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EDINBURGH'S PLACE IN SCIENTIFIC PROGRESS

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EDINBURGH'S PLACE IN SCIENTIFIC PROGRESS

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PREFACE

"EDINBURGH'S Place in Scientific Progress" is a theme whose adequate treatment is beyond the capacity of any single writer. It has, in consequence, received scant attention in the varied and attractive literature called forth by the history and traditions of our city. Only incidentally do our scientific men of the past receive a passing notice from those who have earned our gratitude by rescuing from oblivion the national services, the heroic deeds, the quaint humour and the kindly foibles of our predecessors. This, no doubt, is natural enough. The developments of Science do not appeal to the multitude with the force and fascination of social and political changes, which are ofttimes the outcome of an upheaval of human passions. History of an attractive kind still busies itself with the outstanding personalities of the age that is being depicted. Men and women who fill a large space in the shifting scenes of their time will always receive special homage from those who follow, and round their memories halos of romance will gather and grow in the dimness of the receding past. The brilliant episodes and the pathetic tragedies which spring to mind with the mere mention of Queen Mary and of Prince Charlie never fail to command attention, especially when they can be linked with existing Palace or Castle, or even with the ruins of an ancient Keep. For these and other thrilling tales of long ago, and for lively pictures of life and manners changing with the centuries, we turn with absorbing interest to the pages of Robert Chambers's *Traditions*, Robert Louis Stevenson's *Picturesque Notes*, John Geddie's *Romantic Edinburgh*, Rosaline Masson's *Edinburgh* and the like. Or we delight in those rich records of the past which are poured forth in inexhaustible profusion by the great Sir Walter in such of his tales as touch on Edinburgh life. Yet Sir Walter Scott, President though he was for twelve years of the Royal Society of Edinburgh, found no occasion to refer to the scientific aspects of the life of his native city, except when, as "Malachi Malagrowther," he wrote on questions of currency. In his *Journal* he speaks of a meeting of the Council of the Royal Society convened to consider the question of allowing Robert Knox to read an anatomical paper at the very time when public feeling ran high over the Burke and Hare revelations. In his novels Scott is content to introduce those picturesque purveyors of pseudo-science, the astrologer and the alchemist ; and even the honest-minded Antiquary is made the butt of genial persiflage.

If Sir Walter Scott so neglected the scientific aspect of Edinburgh society, what can we expect in the works of other writers ? Nevertheless, the discoverers of scientific fact and the leaders of scientific thought were, in their day, fully appreciated by their contemporaries. This we may legitimately infer from the legacy of splendid portraits which are now the treasured possession of the University, the Royal College of Physicians, the Royal College of Surgeons and the Royal Society of Edinburgh. Moreover, in addition to these masterpieces by John Graham, Sir Henry Raeburn, Sir John Watson Gordon, Norman Macbeth, Sir George Reid and others, have we not Kay's *Original Portraits and Caricature Sketches*, giving with undoubted fidelity the very features of the men who constituted Edinburgh society during the forty years' span which overlaps and links together the eighteenth and nineteenth centuries? In this altogether unique gallery of Art are portrayed all types of Edinburgh citizens—statesmen, lawyers, clergymen, physicians, historians, philosophers, men of scientific and of literary fame, bankers and even notorious nondescripts who gossiped round the Parliament Square and haunted the contiguous Closes.

Among those depicted who fill a niche in the scientific temple of fame we find—to name a few of the most celebrated—Adam Smith, Cullen, Black, Hutton, Leslie, the two Hopes, Jameson, Benjamin Bell, Andrew Duncan—a goodly list, showing that the artist had a true catholicity of outlook.

To prepare a broad and sufficient view of Edinburgh's contributions to Science, it was obviously necessary to enlist the services of nearly as many authors as there were branches and sub-branches of Science to be presented. In allocating the different sections to appropriate contributors the Editorial Committee invited the co-operation of the expert in each science. As was to be expected, the University has furnished the great majority of these. The Committee met with a cordial response from all whom they approached; and they desire to express their grateful thanks for the admirable way in which, on necessarily very short notice, the material was prepared and made ready for the press. Sir Isaac Bayley Balfour, who willingly undertook to write the section on Botany, was reluctantly compelled, through pressure of work and illness, to demit the task to Mr W. W. Smith. The article, however, has had the advantage of his revision.

Within the limits assigned it is believed that a book of real historic value is being placed in the hands of the members of the British Association—different, indeed, from the usual type of handbook, but presenting a new aspect of the city's influence in human progress. In order to bring the volume within the easy reach of our widely scattered graduates and others interested in Edinburgh, the Committee have taken the unusual step of arranging for its wider publication. They have been fortunate in securing for this purpose the services of W. & R. Chambers, Ltd.

The book is necessarily brief, but its value as a compendium of scientific lore lies at once in this brevity and in the comprehensiveness of its survey. The reader will be able to refresh his memory in regard to the progress of the science of which he is a devotee. At the same time the perusal of the book as a whole will impress upon his mind the vigour and individuality with which the various schools of thought in the capital of Scotland have worked for the good of the community.

The articles are arranged, broadly speaking, in the order of the corresponding sections of the British Association—the physical sciences being followed by the biological, and these again by what more immediately concerns man, physiologically, psychologically and socially. Science in its widest sense rests on education, and the principles underlying a sound system of education were recognised long ago by John Knox and other leaders of the Reformation. Since these days the "lad o' pairts" has never lacked the opportunity of acquiring knowledge for its own sake. To the ferment of the Reformation times we also owe the foundation of the University of Edinburgh, which, steadily growing in power and catholicity, is now the city's chief centre of scientific light and leading. During the first century of its existence, however, the town's College did very little in the teaching of Science. Napier's supreme gift to the mathematical world—the discovery of logarithms in 1614—was an event in no way connected with the University; and it was not till well on in the eighteenth century that a Professor of Mathematics was appointed. The scientific side of the College training was, in the first instance, developed through the influence of a group of energetic and far-sighted men to whom we owe the initiation of the Medical School. Sir Robert Sibbald and Sir Andrew Balfour were eminent physicians, who conjointly secured the establishment of the first Botanic Garden for the study of medicinal plants. Sutherland, the keeper of the Garden, became, in 1673, Professor of Botany, the first Chair founded in what is now the Medical Faculty of the University. Sibbald was also an enthusiastic naturalist and the author of the earliest work on the fauna of Scotland. This direct interest in scientific questions on the part of our leading physicians has been characteristic of the Edinburgh Medical School down the centuries. The famous African traveller, Mungo Park, was a fully qualified medical graduate, and a reference to the articles on Meteorology, Chemistry, Geology, Zoology, Oceanography, Botany and Geography will show how deeply the medical student and graduate of Edinburgh influenced the progress of these sciences. Some, indeed, forsook the professional paths and devoted themselves to scientific research. Many whose main life-work was that of the physician found time and energy to keep in fruitful touch with physical or biological science, and not a few took a keen interest in archaeology and notably advanced the science of anthropology.

The seventeenth and eighteenth centuries were troublous times in politics and religion, and to a reader of ordinary history Scotland appears to have been a most distressful country. Nevertheless the useful life of the community went on. Edinburgh was peopled with men of character and purpose who advanced literature, science and art, undeterred if not undisturbed by the fierce controversies and struggles of the age in which they lived. The spirit of enterprise was in the air. Improvements in agriculture were sought for and found. Banking and credit systems came to the front, with occasional disasters like the Darien Scheme. Political Economy and Philosophy took deep root in the Scottish mind, rising to fruition in the works of David Hume and Adam Smith. Mathematics, under the Gregories and Maclaurin, was studied for its own sake. Geology began to shape itself as a science, with

Hutton, Hall and Playfair as pioneers. New Chairs were created in the University, and the youth of Scotland eagerly sought instruction within her walls. Political revolutions and wars in no way retarded but rather intensified the growing interest in the phenomena of nature, animate and inanimate. Medical and scientific societies sprang into being, the founding of the Royal Society of Edinburgh in 1783 being one among many symptoms of the increasing regard for exact knowledge.

The advancing years of the nineteenth century witnessed a vast improvement in scientific theory, towards which Edinburgh men and men trained in Edinburgh schools gave valuable contributions.

In the fundamental science of Natural Philosophy important discoveries in radiation, conduction, and transformation of heat were made by Leslie, J. D. Forbes, Balfour Stewart, Waterston and Rankine; our knowledge of the phenomena of light was greatly extended by Brewster; the doctrine of energy was developed and explained by Tait; the laws of atmospheric pressure were notably elucidated by Buchan; while Maxwell's comprehensive theory of light and electricity was the direct precursor of wireless telegraphy and the modern doctrine of Relativity. The foundations of the science of Oceanography were laid by Edward Forbes, Wyville Thomson, and John Murray. Outstanding among geographical discoveries were the determination of the source of the Blue Nile by James Bruce and the tracing of the Niger by Mungo Park. In many ways medical and surgical science has been advanced; but we can only mention here John Goodsir's pioneer work in cell-life; Robert Christison's investigations in the action of various poisons on the human system; Charles Bell's discoveries in the nervous system; James Young Simpson's introduction of anæsthetics; and Joseph Lister's revolutionary work in antiseptic surgery. These are a few of the scientific discoveries made by Edinburgh men in the century that has passed; and in the century that has begun the work of Sir David Bruce on sleeping sickness calls for particular mention.

The whole record is a great one for any single city, and, thankful for the splendid tradition bequeathed us by our predecessors, we look forward to a future full of promise for the advance of knowledge and the furtherance of the welfare of mankind in those fields in which Edinburgh has already secured an honourable place in the history of scientific progress.

C. G. K.

CONTENTS

I

PAGE

MATHEMATICS AND NATURAL PHILOSOPHY . . . 1
By CARGILL G. KNOTT, D.Sc., LL.D., F.R.S., General Secretary, Royal Society of Edinburgh, Reader in Applied Mathematics, University.

ASTRONOMY 31
By R. A. SAMPSON, M.A., D.Sc., F.R.S., F.R.S.E., Astronomer Royal for Scotland, Professor of Astronomy, University.

ACTUARIAL SCIENCE 33
By A. E. SPRAGUE, M.A., D.Sc., P.F.A., F.I.A., Lecturer in Actuarial Science, University.

METEOROLOGY 36
By ANDREW WATT, M.A., F.R.S.E., Meteorological Office, Air Ministry.

II

PURE CHEMISTRY 44
By LEONARD DOBBIN, Ph.D., F.R.S.E., Reader in Chemistry, University.

INDUSTRIAL CHEMISTRY 54
By A. P. LAURIE, D.Sc., F.R.S.E., Principal of Heriot-Watt College.

SHALE OIL INDUSTRY 58
By D. R. STEUART, F.I.C., F.R.S.E., Chemist to Broxburn Oil Company.

III

GEOLOGY 63
By E. B. BAILEY, B.A., F.G.S., F.R.S.E., and D. TAIT, of H.M. Geological Survey of Scotland.

IV

PAGE
ENGINEERING 100
By T. HUDSON BEARE, B.A., B.Sc., M.Inst.C.E., F.R.S.E., J.P., D.L., Professor of Engineering, University.

V

ZOOLOGY 113
By JAMES RITCHIE, M.A., D.Sc., F.R.S.E., Keeper of Natural History Department, Royal Scottish Museum.

VI

OCEANOGRAPHY 126
By W. A. HERDMAN, C.B.E., D.Sc., LL.D., F.R.S., F.R.S.E., F.L.S., Professor of Oceanography, University of Liverpool.

VII

BOTANY 145
By W. W. SMITH, M.A., F.R.S.E., Assistant Keeper, Royal Botanic Gardens.

FORESTRY 158
By SIR JOHN MAXWELL STIRLING-MAXWELL, Bart., B.A., D.L., M.P.

VIII

AGRICULTURE 162
By J. A. S. WATSON, B.Sc., F.R.S.E., Lecturer in Agriculture, University.

IX

GEOGRAPHY 168
By G. G. CHISHOLM, M.A., B.Sc., Reader in Geography, University, and Secretary of the Royal Scottish Geographical Society.

X

ANTHROPOLOGY 176
By J. H. CUNNINGHAM, F.S.A.Scot.

PHYSICAL ANTHROPOLOGY 186
By ARTHUR ROBINSON, M.D., F.R.C.S., F.R.S.E., Professor of Anatomy, University.

XI

PAGE

MEDICINE (TO 1870) 188

By J. D. COMRIE, M.A., B.Sc., M.D., Lecturer in History of Medicine, University.

SURGERY 212

By ALEXANDER MILES, M.D., Senior Lecturer in Clinical Surgery, University.

MEDICINE (FROM 1870) 223

By JAMES RITCHIE, M.A., M.D., Professor of Bacteriology, University.

XII

DENTISTRY 235

By WILLIAM GUY, F.R.C.S., L.R.C.P., F.R.S.E., L.D.S.Ed., Dean of the Edinburgh Dental Hospital and School.

XIII

POLITICAL ECONOMY 238

By J. SHIELD NICHOLSON, M.A., D.Sc., F.R.S.E., Professor of Political Economy, University.

XIV

PSYCHOLOGY 245

By JAMES DREVER, M.A., B.Sc., D.Phil., Reader in Psychology, University.

XV

EDUCATION. 252

By JAMES DREVER, M.A., B.Sc., D.Phil., Reader in Psychology, University.

XVI

SOCIAL REFORM 257

By NORA MILNES, B.Sc., Director of the Edinburgh School of Social Study and Training, under the Auspices of the University.

PORTRAITS

John Napier of Merchiston . . . *Frontispiece*
Joseph Black . . . . . *Facing page* 48
James Hutton . . . . . ,, 80
James Nasmyth . . . . ,, 112
Edward Forbes . . . . ,, 144
James Young Simpson . . . ,, 192
Joseph Lister . . . . . ,, 224
Adam Smith . . . . . ,, 240
David Hume . . . . . ,, 256

EDINBURGH'S PLACE IN SCIENTIFIC PROGRESS

I

MATHEMATICS AND NATURAL PHILOSOPHY

Astronomy—Actuarial Science—Meteorology

THE first man of "science" whom Scotland produced was Michael Scot the wizard, said to have been born at Balweary, near Kirkcaldy, within the circuit of vision of Edinburgh. Manuscripts of his on Astrology exist in the University Library. Therein he is designated Astrologer to the Emperor Frederic II (1194–1250). The exact span of his life is unknown, but his European fame in the thirteenth and fourteenth centuries was great enough to entitle him to a place in Dante's *Inferno*. Astrologers were the mathematicians, the chemists, the astronomers of the Middle Ages; and out of the knowledge and superstition of these times modern science has sprung.

In the light of accurate history, however, John Napier of Merchiston (1550–1617) stands pre-eminent as the first great scientific Scotsman. Merchiston is a district of Edinburgh City, and Napier's old castle exists as part of a high-class boarding-school for boys. Seven years ago, in June 1914, the Royal Society of Edinburgh organised an International Congress in memory of this illustrious mathematician, the discoverer of the logarithmic function and the inventor of logarithms. Outstanding mathematicians from the various countries of the world joined in eulogy of the man who, three hundred years earlier, had given to humanity a method which made possible calculations never before even dreamed of. His *Mirifici Logarithmorum Canonis Descriptio* (1614) marks an epoch in the history of mathematics. The publication of the small quarto volume of 156 pages, and measuring 7 inches by 5 inches, was an event of scientific importance of incomparably greater magnitude than any other advance in science accomplished by an Edinburgh citizen. With the exception of Newton's *Principia*, which appeared seventy-two years later, no other work published in Great Britain has had a more profound and far-reaching influence on the progress of science than Napier's little book.

The secondary title of the *Descriptio*, as translated in Wright's English edition (1618), explains the treatise as "a declaration of the most Plentifull, Easie, and Speedy use thereof in both kinds of Trigonometry, as also in all Mathematical Calculations." The tables, in fact, in their first form give the so-called logarithms of the sines of the angles from 0° to 90°; and the logarithms are so arranged that the number whose logarithm is zero is 10,000,000, the sines being measured in terms of this as radius of the related circle. This system of logarithms corresponds neither to the Common Logarithm familiar to all nowadays, nor to the system usually designated Napierian Logarithms; although there is a very close relationship which need not be discussed here. It early became the custom, however, to distinguish between the Natural or Napierian system and the Common or Briggsian system of logarithms; and until lately it was a popular conception that the common logarithm to base 10 was as much the invention of Henry Briggs, Professor of Geometry in Gresham House, London, as the earlier was the invention of Napier. But Briggs's own account of his interview with Napier as given in the preface to his *Arithmetica Logarithmica* of 1624 shows without a doubt that it was Napier who suggested the calculations of logarithms to base 10.

In Briggs's statement, as translated by G. A. Gibson in his article on *Napier's Logarithms and the Change to Briggs's Logarithms* (Napier Memorial Volume, 1915), these words occur : " As we talked over the change in the logarithms he (Napier) said that he had for some time been of the same opinion and had wished to accomplish it ; he had, however, published those he had already prepared until he could construct more convenient ones if his affairs and his health would admit of it. But he was of opinion that the change should be effected in this manner, that 0 should be the logarithm of unity and 10,000,000,000 that of the whole sine : which I could not but admit was by far the most convenient. So, rejecting those which I had previously prepared, I began at his exhortation to meditate seriously about the calculation of these logarithms ; and in the following summer I again journeyed to Edinburgh and showed him the principal part of the logarithms I here submit."

But apart altogether from methods of calculation, the unique scientific value of Napier's conception was the clear presentation of the logarithmic function and the closely related exponential function, conceptions which are at the very foundation of analysis and of all kinds of applications in physical science. Napier practically defined the logarithm of a number as that number which increases by equal increments in successive equal times during which the number itself diminishes proportionately to its momentary value, or symbolically $dy = -dx/x$, where y is the logarithm of x. To integrate this equation is a very simple matter now, when we have a convenient and expressive notation. But in Napier's day there was no notation, no symbolism ; yet with what amazing clearness and precision he grasped the essence of the conception !

In the *Descriptio*, after a brief explanation of the meaning of the logarithm, Napier limits himself entirely to its use in trigonometrical calculations. He had, however, prepared another volume on the method of the Construction of his logarithmic tables, which was published two years after his death by his son Robert, under the title *Mirifici Logarithmorum Canonis Constructio* (1619). The earlier part of the *Constructio* was written before the final preparation of the *Descriptio*; but two appendices are added, the one on the making of another and better kind of logarithm, obviously that committed to the care of Briggs, and the other on "the Solution of Spherical Triangles by an easier method: with Notes by the learned Henry Briggs." Thus these two small books contain not only the basis of the theory and practice of logarithms but also the Rules of Circular Parts and the Analogies in Spherical Trigonometry which alone would have given Napier a place in the history of mathematical science.

On the more practical side of logarithmic calculations and the preparation of logarithmic tables, Edinburgh has continued to take a considerable interest during the last hundred years. Shortrede's seven-place logarithms of numbers and of the trigonometrical functions tabulated to every second of angle with various other tables useful in astronomy and geodesy (1844) was a serviceable compilation. It was edited chiefly by Edward Sang, of whom more hereafter; and its best features were embodied in the well-known set of seven-figure mathematical tables published by W. & R. Chambers. Erskine Scott, a native of Edinburgh, prepared in 1892 tables of five-figure logarithms and anti-logarithms which are unique in giving both numbers and logarithms complete to five figures, so that the worker never requires to interpolate by proportional parts.

Edward Sang devoted the greater part of a long and active life to logarithmic calculations. He calculated to as many as twenty-eight figures the logarithms of all prime numbers up to 10,037 and a few beyond, and from these, with the help of his daughters, he constructed a great table of logarithms to fifteen figures with first and second differences for all integers from 100,000 to 370,000. The natural limitations of life prevented him carrying on to the million, as originally intended. The forty manuscript books containing these logarithms were presented to the British nation by his daughters, and are now in the custody of the Royal Society of Edinburgh for use and reference. A full account of their construction will be found in C. G. Knott's article on *Edward Sang and his Logarithmic Calculations*, published in the Napier Memorial Volume.

It was probably from the astronomical side that Napier approached the question of improving methods of calculation ; and astronomy, both on its observational and mathematical aspects, has always had a strong attraction for minds scientifically inclined.

Thus James Gregory (1638–74), Professor of Mathematics first in St. Andrews and then in Edinburgh, invented the reflecting telescope known by his name. The description is contained in his *Optica Promota* (1663), in which a full discussion is given of the reflection and refraction of light by mirrors and lenses. In this book also he first suggested measuring the sun's parallax by observation of the transits of Venus or Mercury across the sun's disk ; and in a later treatise, *Geometriae Pars Universalis* (1668), he describes, also for the first time, the method of estimating the parallax of the fixed stars by comparing their brightness with that of the sun.

James Gregory was not only the first great mathematician in Edinburgh after Napier, but he continues to rank among the greatest. An Aberdonian by birth and education, he spent several years at the University of Padua, where his two treatises, *Vera Circuli et Hyperbolae Quadratura* and *Geometriae Pars Universalis*, were published together in 1668. As appears from the published correspondence with Collins, Newton and others, Gregory was the discoverer of various series, notably that which expresses the arc in terms of the tangent. He introduced the term "convergent series"; and to him also was due the interpolation formula commonly called Newton's. He occupied the Chair in Edinburgh for little more than one year, being suddenly stricken down by apoplexy at the early age of thirty-seven.

Eight years later, in 1683, his nephew, David Gregory, was elected professor. His works on Optics embodied much of his uncle's manuscript notes, and retained for long a high reputation. He was an intimate friend of Newton, through whose influence he became (1691) Savilian Professor of Astronomy at Oxford. His successor in Edinburgh was James Gregory, his half-brother. Through the influence of the three Gregories the Newtonian philosophy was more effectively studied in the Scottish Universities than even in Cambridge; and the good work was continued with even greater zeal by Colin Maclaurin (1698–1746), who occupied the Chair in Edinburgh from 1725. Like his contemporary and friend, James Stirling (1693–1770), Maclaurin has left his mark on mathematical developments, both in analysis and in the geometry of curves. Stirling's and Maclaurin's theorems are frequently referred to in modern treatises. In their lifetime they were in friendly intimacy, not only with each other but with the great mathematicians of England and the Continent. In addition to original papers of high merit, Maclaurin enriched the mathematical literature of the eighteenth century by four remarkable works: *Geometria Organica* (1718), a *Treatise on Fluxions* (1742), a *Treatise of Algebra* (1748) and an *Account of Sir Isaac Newton's Philosophical Discoveries* (1748). The last two were published after his death. The *Fluxions* had its origin in the famous attack made by Berkeley upon the logic of the fluxional or differential calculus. Maclaurin resolved to combat the great philosopher's criticism; but as he proceeded he wisely forsook the more polemical path and evolved a treatise which, if cast into more modern form, would prove an excellent text-book on the calculus and its applications. After an introduction in which the method of exhaustions as practised by Archimedes is fully explained, Maclaurin proceeds to develop at considerable length Newton's conception of the Fluxion, basing upon the idea of continuous motion, and applying Newton's principle of limits of ratios of simultaneous changes. Most skilfully does Maclaurin apply the method in the discussion (1) of curved lines with their tangents, asymptotes, curvatures, evolutes and involutes; (2) of central forces, gravitation, lunar motions, and the gravitation of rotating fluids. This completes the first volume. In the second volume he passes on to the more difficult questions of paths of shortest time, of solids of least resistance, the gravitation attraction of spheres and spheroids, tides and the figure of the earth. At this stage the more purely geometrical methods of proof give way to analytical methods by means of series, in which Stirling's investigations are particularly referred to, as well as those of Newton and Cotes. In the second part of volume ii the theory of fluxions is developed analytically along with the converse method of fluents or integration. Integration and interpolation by series are discussed in detail; and then, with the general rules now at command, Maclaurin continues the discussion of geometrical and dynamical problems. Maclaurin was keenly interested in the whole range of mathematical and physical science, and for some years his college rooms were used as an optical workshop by James Short (1710–68), a native and graduate of Edinburgh, who subsequently in London enjoyed a high reputation as a maker of reflecting telescopes. He was the first to make parabolic specula, to which he imparted a fine lasting polish.

Maclaurin's influence as a man of affairs extended far beyond the mathematical horizon. He was active in many schemes for the public benefit, such as the improvement of geography and navigation. He helped materially in establishing, on a sound actuarial basis, the Widows' Fund for the Scottish Clergy and the Professors in the University. Having taken a leading part in fortifying Edinburgh against the advance of

Prince Charlie in 1745, he was compelled to flee for refuge to York until the brief Jacobite triumph had ended in disaster. On his journey back to Edinburgh he caught a chill which so undermined his health that he died within the year at the age of forty-eight.

Stirling was invited to become a candidate for the vacant chair; but belonging as he did to a family of strong Jacobite sympathies he declined to complicate a troublesome situation by coming forward. The choice fell on Matthew Stewart, pupil and friend of Robert Simson of Glasgow, and an accomplished geometrician. His *General Theorems of use in Higher Mathematics* (1746) and his *Propositiones Geometrica* (1763) gained him a high reputation, especially among the French geometricians (see Chasles' *Aperçu Historique*).

Napier, James Gregory, Stirling and Maclaurin are names which secure for Scotland a high rank in the history of Mathematics.

Meanwhile, during the eighteenth century, observational science was being more and more cultivated, especially by men whose medical studies brought their minds into touch with the fundamental sciences of physics, chemistry, meteorology and biology. A Society for the Publication of Medical Essays came into existence in 1731; and in 1739, this Society became the Philosophical Society of Edinburgh, with Maclaurin, Stirling, James Short and others among its non-medical members. Three volumes of *Essays and Observations, Physical and Literary*, were published in the years 1748, 1756 and 1774. In the first volume there are two papers by Maclaurin: one on the Variation of the Obliquity of the Ecliptic, and the other on Changes observed in Jupiter's Surface. The second volume contains a thoughtful paper on Light and Colours by Thomas Melville, M.A., who died at the age of twenty-seven in 1753, the year after the paper had been read before the Society. Melville accepts the corpuscular theory as the basis of his discussions, but points out very clearly the difficulty of understanding the non-entanglement of rays of light crossing one another as they pass in all directions through space. He describes experiments showing how the colours of bodies change according to the nature of the light which illuminates them; and improves on Newton's treatment by explaining the yellow, orange and red colours at sunset as being due to the fact that the particles in the air reflect the violet and blue rays more abundantly than the rest, so that "the sun's light, transmitted through it, ought to draw toward yellow, orange or red; especially when it passes through the greatest tract of air."

In the same volume Professor Cullen of Glasgow describes experiments on the Cold produced by Evaporating Fluids, the subject having been suggested to him by a remark made by one of his pupils. This was none other than Joseph Black, afterwards the eminent Professor of Chemistry in Edinburgh, whose discovery of Latent Heat in 1762 gave the immediate explanation of Cullen's observations. Black's theory of Latent Heat was explained to the Philosophical Club or Society of Professors in Glasgow, but was never published till it appeared in Black's *Lectures*, edited by Robison in 1803. The practical importance of Black's discovery was, however, at once recognised by his contemporaries, especially by James Watt, whose genius transformed latent heat into useful mechanical work.

In 1783 the Philosophical Society was reorganised into the Royal Society of Edinburgh, with a royal charter which designated it as a Society for Promoting Science and Literature. Round this Society, which has always been closely associated with the University teachers, the scientific activities of Edinburgh have ever since continued to cluster. The history of scientific progress in the nineteenth century and the later years of the eighteenth century is embodied in the many valuable contributions to its *Transactions* and *Proceedings*.

The immediate successors of Maclaurin in the Chair of Mathematics did not add materially to the progress of the science. Dugald Stewart succeeded his father

Matthew in 1775, but was transferred in 1785 from the Chair of Mathematics to that of Moral Philosophy, which he filled with brilliant efficiency till 1810. His colleague in the Chair of Natural Philosophy was John Robison (1739–1805), of whom there exist two exquisite portraits by Sir Henry Raeburn, the one in the University Senate Hall, the other in the Royal Society Reception Room.

Robison was the first general secretary of the Royal Society of Edinburgh, initiating a succession of general secretaries who, with the single exception of Professor J. H. Balfour, the botanist, were all Natural Philosophers in the recognised sense of the term. He was an intimate friend of James Watt, who said of Robison : " He was a man of the clearest head and the most science of anybody I have known." His paper on *The Motion of Light as affected by refracting and reflecting substances, also in motion* (*Trans. R.S.E.*, ii, 1787) marks him as one of the pioneers in those investigations which in our own time have culminated in the theory of Relativity (See Whittaker's *History of the Æther*, p. 116.) Robison had a wide and accurate knowledge of Physical Science, especially on the engineering and technical side. His contributions to the *Encyclopædia Britannica* (7th edition) on all branches of natural philosophy were recognised as of the highest value by his contemporaries ; and a selection of them was afterwards edited by Sir David Brewster in four volumes entitled *Robison's Mechanical Philosophy*. Of recent years the ball-ended magnets invented by Robison have proved very serviceable in certain lines of magnetic research.

The nineteenth century witnessed an extraordinary development, both in knowledge of phenomena and in far-reaching theories of pregnant significance. In this development the Fellows of the Royal Society of Edinburgh took an active share.

In pure mathematics, however, there was a distinct set-back in the early years of the century. Both John Playfair (1748–1819) and John Leslie (1760–1832), who each occupied in succession the Chairs of Mathematics and Natural Philosophy, communicated mathematical papers of interest to the Royal Society of Edinburgh; but their real strength lay in observational and experimental science. The one strong mathematician of that time to whom Edinburgh can lay some claim was James Ivory (1765–1842). He studied at St. Andrews along with John Leslie; and the two friends proceeded to Edinburgh University in 1784 with a view to theological studies, which neither, however, pursued to the end. Between 1793 and 1802, Ivory communicated three mathematical papers to the Royal Society of Edinburgh, the last being a *New and Universal Solution of Kepler's Problem*. He subsequently became mathematical professor in the Military College of Great Marlow (afterwards removed to Sandhurst), and attained a high reputation in scientific circles. He was knighted in 1831. A large number of papers on the theory of attraction and on atmospheric refraction bear witness to his activity; and he was the author of an important theorem, called Ivory's Theorem, on the law of attraction of an ellipsoid (*Phil. Trans.*, 1809). It is described in all treatises on the subject, and forms an important link in the chain of investigations in this fascinating and difficult study from the days of Stirling, Maclaurin and Clairault to the present-day refinements of Poincaré, Darwin and Jeans.

Associated for a few years with Ivory at Great Marlow was William Wallace (1768–1843), who succeeded John Leslie in the Chair of Mathematics in Edinburgh in 1819. He is best known as the inventor of the pantograph and the eidograph. He retired in 1838 and was succeeded by Philip Kelland (1808–79), a senior wrangler of Cambridge of high distinction. Kelland's most important contributions are his papers on General Differentiation, on the Theory of Waves, and on the Theory of Parallels (*Trans. R.S.E.*, xiv–xxiii). In these as in his other writings he shows both power and elegance. There are many who still remember the genial teacher whose solutions of problems were always so clear and complete.

Edinburgh also claims as one of her mathematical sons Duncan Farquharson Gregory (1813–44), son of Dr James Gregory, Professor of Medicine in the University, and great-grandson of James Gregory *primus*. He was one of Wallace's favourite pupils, and after some time at Edinburgh University he proceeded to Cambridge, where he became in due course the first editor of the *Cambridge Mathematical Journal* (1837). His paper on the *Real Nature of Symbolical Algebra* (*Trans. R.S.E.*, xiv, 1838) deals with the general subject of treating symbols as quantities. Many of his other papers in the *Cambridge Mathematical Journal* give important illustrations of the same method of separation of symbols. The method is much in evidence in his treatise, *Collection of Examples of the Processes of the Differential and Integral Calculus* (1841), a book which students will still find useful and exhilarating. After two years' suffering he died at Edinburgh at an earlier age even than his illustrious ancestor.

George Chrystal (1851–1912), after a distinguished mathematical career at Aberdeen and Cambridge, became Professor of Mathematics in St. Andrews University in 1877, whence he was transferred to Edinburgh University in 1879. He revolutionised the whole teaching of mathematics in the University, and by supplying a steady stream of highly trained teachers he powerfully influenced the teaching in the schools of Scotland. His *Algebras* are still recognised as valuable and inspiring text-books. In Cambridge he came under the influence of Clerk Maxwell, one of the scientific geniuses of all time; and although he contributed several purely mathematical papers to the Royal Society of Edinburgh, notably an excellent presentation of non-Euclidean Geometry, his most important work was on the physical side, and will be considered later.

In 1882 the Edinburgh Mathematical Society was started, at the suggestion of A. Yule Fraser, an

Aberdonian graduate, at that time mathematical master in George Watson's College, whose early death some years later in Glasgow was a serious loss to mathematical science. The first secretary of the Society was C. G. Knott; and fostered by Chrystal, Thomas Muir of Glasgow and J. S. Mackay of Edinburgh, the Society rapidly became an active centre for mathematical discussion and publication. Mackay's geometrical papers, largely historical, give a special character to the earlier volumes of the *Transactions*. In recent years analysis rather than geometry has occupied the attention of the members, mainly under the guiding influence of E. T. Whittaker, the present occupant of the Chair of Mathematics. Through his activity and organising skill there has also been established in the University of Edinburgh a strong Research School in Mathematics, with a Mathematical Laboratory in which training in the higher calculations forms a unique feature. In this connection it is worthy of note that the most complete mathematical tables ever published by the Royal Society of Edinburgh are the tables of the error function elaborately worked out by Dr James Burgess, C.I.E. (*Trans. R.S.E.*, xxxix, 1897).

Thomas Muir—now Sir Thomas, and from 1892 to 1915 Superintendent-General of Education in Cape Colony—has not allowed administrative duties to interfere with his mathematical work. He is the recognised authority on all questions connected with the theory of Determinants. His numerous historical contributions to the Royal Society of Edinburgh have been collected in book form in his *Theory of Determinants in the Historical Order of Development*, of which three volumes have been published (1906–20). No mathematician's library is complete without these books of reference.

During the nineteenth century it was Natural Philosophy, both on its experimental and mathematical sides, which most strongly attracted teachers and students alike in Edinburgh and throughout Scotland.

The great variety and importance of the work done can best be judged by glancing through the *Transactions* and *Proceedings of the Royal Society.*

In 1800 we find Thomas Charles Hope (1766–1844), Black's successor in the Chair of Chemistry, describing his experiments on the contraction of water by heat. One form of apparatus invented by him is described in text-books under the name of "Hope's experiment."

In 1802, as Editor of the *Edinburgh Magazine*, David Brewster (1781–1868) began his long and highly distinguished career as the prince of investigators in the optical properties of substances. He wrote numerous papers on polarisation, diffraction, dichroism, phosphorescence, indeed, on every possible branch of optics, discovering the important law which bears his name, and receiving in 1815, while still comparatively young, the Copley Medal from the Royal Society of London. He invented the kaleidoscope and greatly improved Wheatstone's stereoscope. Brewster began his optical researches at a time when the undulatory theory of light was taking shape in the hands of Thomas Young (1773–1829) and A. J. Fresnel, the eminent French mathematician. Young, it may be mentioned, spent the session 1794–95 at the University of Edinburgh as a medical student and attended the classes of Gregory, Duncan and Black; and the second edition of his great *Lectures on Natural Philosophy* was edited by Kelland in 1845. Notwithstanding the exquisite way in which the wave theory of light explained the beautiful phenomena of polarisation and diffraction, Brewster never fully accepted the lead of Young and Fresnel. Certain theories of colour which he put forward found few adherents among other workers in the same field. None the less, Sir David Brewster (he was knighted in 1832) was a brilliant investigator and left behind him an immense literature, not only of high-class original memoirs, but also of encyclopædia articles and books which are still of service to the student. His *Life of Newton* in two volumes (2nd edition, 1855) is particularly important, although he was not fitted to discuss adequately the mathematical side of Newton's profound genius. Honours innumerable were showered upon him by national Academies and Institutes. He occupied the position of Principal, first, of the United Colleges of St. Andrews (1838–59) and finally of Edinburgh University (1859–68).

John Leslie, even while resident in Edinburgh as Professor of Mathematics (1805) and later of Natural Philosophy (1819–33), did not contribute many papers to the Royal Society. After some years spent in travel, he settled in Largo, his native town, and devoted himself to research. Here he invented his Differential Air Thermometer, which first took shape as a hygrometer. This instrument, although completely superseded before 1840 by delicate electrical methods for measuring temperature changes, was in its day far superior as regards sensitiveness to any other form of thermoscope. Leslie's growing reputation, both at home and abroad, as an experimenter of genius was established beyond controversy by the publication of his treatise, *An Experimental Inquiry into the Nature and Propagation of Heat* (1804). In Note xvi to this work on *Heat* occurs the sentence praising David Hume as the "first who treated of causation in a truly philosophic manner"—which was seized hold of as a reason for fierce protest against Leslie being appointed Professor of Mathematics. He was accused of being an atheist. Even after his election by the Town Council the agitation continued, fomented by a group of irreconcilables. Only by an adverse vote in the General Assembly of the Church of Scotland was this heresy-hunting minority finally silenced.

The book on *Heat* contains many striking experiments, notably those with the cubical box ("Leslie's Cube"), by which he demonstrated the different emissive powers of different surfaces at the same temperature. Leslie regarded Radiant Heat as being propagated through the atmosphere in the form of oscillations or vibratory impressions excited in that elastic and active medium. The theory is vague and incapable of development; and in the light of subsequent knowledge it seems extraordinary that an acute thinker like Leslie, steeped in all the facts of radiation, should have missed what is now the obvious physical identity of light and radiant heat. This is the more surprising inasmuch as he uses his differential thermometer as a photometer, and describes many phenomena depending on the absorption of light by a blackened bulb and its transformation into heat.

A very famous experiment due to Leslie is that in which water is made to boil at a low pressure and temperature, and by its rapid evaporation to become cooled and frozen. In other words, it freezes in the act of boiling. To carry out the experiment successfully the partial vacuum in which the evaporation is being promoted must be kept dry. This Leslie effected first by use of roasted oatmeal, and finally by use of strong sulphuric acid. The apparatus which Leslie himself used is still extant in the Natural Philosophy Museum; and the experiment was shown every year to the class of Natural Philosophy by Forbes, Tait and MacGregor in succession.

Christopher North (Professor John Wilson) in his *Chaldee Manuscript*, which forms part of the *Noctes Ambrosianae*, refers in these words to Leslie's experiment:

" 20¶ Then the man called with a loud voice on some other spirits, in whom he put his trust.

" 21 And the first was a cunning spirit which hath his dwelling in the secret places of the earth, and hath command over the snow and the hail, and is as a pestilence unto the poor man; for when he is hungry he lifteth up the lid of his meal-girnel to take out meal, and lo! it is full of strong ice."

Sir John Leslie was an ardent meteorologist, and a selection of his various articles in the *Encyclopædia Britannica* was published in 1838 in book form under the title, *Treatises on Various Subjects of Natural and Chemical Philosophy*.

It is fitting to mention at this stage the name of James Lindsay, who entered the service of Leslie in 1814 and in 1819 became mechanical assistant to the Natural Philosophy Chair. In this capacity he served Leslie, Forbes and Tait, helping greatly in the experimental researches of all. He was succeeded by his son Thomas, who with scientific aptitude even greater than his father's was a familiar figure to the generations of students who attended the Natural Philosophy and Physics classes from 1870 to 1918. For nearly a century the Lindsays, father and son, had charge of the apparatus in the Natural Philosophy Museum, prepared the experimental illustrations for the lectures, and aided the professor in research.

One of the most brilliant students of Wallace and Leslie was Edward Sang (1805–90), already referred to in connection with the history of logarithms. He was a mathematician of very original powers. His *New General Theory of the Teeth of Wheels* (1852) is the recognised classic on the subject. In a paper read before the Society of Arts he anticipated by twenty years the application by Foucault of the gyroscope to demonstrate the rotations of the earth. Through the inexplicable action of the officials of the Royal Society of Edinburgh an important paper by Sang, of date 1837, was neglected and left lying in a drawer till rescued from oblivion by Tait fifty-four years later. William Nicol, an Edinburgh physicist and naturalist, had in 1829 (*Edin. New Phil. Journ.*) invented the polarising prism known by his name—a piece of apparatus absolutely invaluable in certain kinds of optical work. The true theory of the Nicol Prism was not clearly understood even by its inventor; but in this neglected paper by Edward Sang the mathematical theory is given completely for the first time. It also contains the suggestion, made forty-seven years later by M. E. Bertrand in the *Comptes Rendus*, that a polariser might be constructed of two glass prisms separated by a suitably placed thin layer of Iceland spar. This

Investigation of the Action of Nicol's Polarising Prism (1837) was subsequently published in full with notes by Tait (*Proc. R.S.E.*, xviii, 1891).

J. J. Waterston (1811–84) is another Edinburgh man who suffered neglect in similar fashion, this time at the hands of the Royal Society of London. His paper *On the Physics of Media that are composed of Free and Perfectly Elastic Molecules in a State of Motion* was read before the Royal Society on March 5, 1846, but published only in abstract and that of a most inadequate description. One important law given in the paper was stated briefly in the *Report of the British Association* for 1851—the law being none other than that subsequently enunciated by Maxwell, the law of the equipartition of kinetic energy among the molecules of a gas at one and the same temperature. As pointed out by Lord Rayleigh, who recovered the original paper from the archives of the Royal Society, and published it in the *Philosophical Transactions* of 1892, this law should henceforth be called Waterston's Law of Equipartition. This paper also contained a new chemical notation which is practically identical with the modern notation.

Thomas Graham (1805–69), after taking his Arts degree in Glasgow, spent five years in Edinburgh University under Hope and Leslie. He contributed four papers on Chemistry to the Royal Society of Edinburgh and one on Physics—the last being the great paper on the *Law of the Diffusion of Gases* (*Trans. R.S.E.*, xii, 1831). This and his later papers on the diffusion of liquids are classical in the history of the development of molecular physics. His high distinction as a chemist and physicist led to his appointment as Master of the Mint in 1855.

Leslie's successor in the Natural Philosophy Chair was James David Forbes (1809–68). Although only twenty-seven when he was elected to the chair, he was already well known to the scientific world, having been elected a Fellow of the Royal Society of Edinburgh when he was twenty-one, and of the Royal Society of London three years later. He was from boyhood keenly interested in meteorological phenomena, and resolved to devote his main attention to the study of the laws of heat. He proved the polarisation of radiant heat transmitted through tourmaline, investigated the thermal conductivity of metals and was the first to study the variation of temperature with depth below the surface of the earth by means of long-stemmed thermometers, whose bulbs reached to depths of 6, 12, 24 and 48 feet. From observations made with a theodolite, Forbes measured the rate of motion of glaciers and proved that they move down their valleys like a viscous fluid, the middle moving faster than the sides and the upper portions faster than the lower. On this subject of glacier motion he wrote several books and numerous papers. In order to measure the earthquakes at Comrie he invented a form of seismograph in which a steady mass with small stability was obtained by using an inverted pendulum supported by an elastic wire. This is the first instance of a seismometer being constructed on scientific principles; and in his paper (*Trans. R.S.E.*, xv, 1842) the word "seismometer" is used for the first time. On his appointment as Principal of the United Colleges of St. Andrews in 1859 he resigned his Chair.

Through Forbes's classes there passed in succession five students who take high rank in the scientific temple of fame—J. Allan Broun (1817–79), Macquorn Rankine (1820–72), Balfour Stewart (1828–87), Peter Guthrie Tait (1831–1901) and James Clerk Maxwell (1831–79); while in the West of Scotland were being trained James Thomson (1822–92) and William Thomson (1824–1907), the illustrious Lord Kelvin. The discoveries and discussions of these intimate friends form a unique period in the history of scientific progress, not only in Scotland but the wide world over.

Sir Thomas Makdougall Brisbane (1773–1860), after whom the capital of Queensland and the associated river are named, was President of the Royal Society of Edinburgh for the last twenty-eight years of his life. He communicated several astronomical papers to the Society before 1825, but his main contribution to scientific progress was the establishment of a meteorological and magnetic observatory at Makerstoun, near Kelso, under the charge of John Allan Broun. The Makerstoun Observations from 1841 to 1846 and their discussion by Broun fill three volumes of the Edinburgh *Transactions* ; and a continuation, edited by Balfour Stewart, forms a supplement to volume xxii. Broun's later work at Trevandrum (1852–65), certain conclusions from which were published by the Royal Society of Edinburgh (*Trans. R.S.E.*, xxiv, xxvi, 1867–72), is of great importance in relation to the diurnal variations of the magnetic declination. He first established the fact that the changes in the daily mean horizontal force are nearly the same all over the globe, proved the existence of a magnetic period of twenty-six days, and was one of the discoverers of the lunar diurnal variation of the magnetic declination, showing that it altered in character with the position of the sun, and varied inversely as the cube of the moon's distance. Broun, of all Edinburgh's scientific sons, did more than any other single worker to bring to light the hidden mysteries of magnetic variation (see *Nature*, Dec. 1879).

Rankine was born in Edinburgh and educated at the Royal High School and the University. As Professor of Engineering in Glasgow University from 1855 his influence as teacher and author was profound and lasting, and his various manuals are still in use among real students of engineering theory and practice. On the theoretical side, Rankine is to be regarded as one of the founders along with Clausius and Kelvin of the modern doctrine of Thermodynamics. In his paper of 1850, *On the Mechanical Action of Heat* (*Trans. R.S.E.*, xx), he deduces the second law of thermodynamics from a special hypothesis of molecular vortices (they are now called electron whirls); and the same hypothesis is made the foundation of mathematical investigation into the laws of elasticity. His discussion of the transformations of energy, the efficiency of engines, and the practical significance of Carnot's principle influenced deeply the scientific thought of his time; and he it was who introduced the convenient term "Potential Energy" in contrast with "Actual" or "Kinetic Energy" as it was subsequently named by Thomson and Tait.

James Thomson, who succeeded Rankine in the Glasgow Chair of Engineering, published comparatively little, but what he wrote was of high scientific value. The prediction of the lowering of the freezing-point of water by pressure (*Trans. R.S.E.*, xvi, 1849) and his subsequent explanation of regelation and glacier motion, his theory of elastic fatigue, and his discussion of the undermining action of streams sweeping round their curved banks, are worthy of mention. The first paper is of great interest as being one of the earliest deductions from Carnot's Principle; it was soon after tested experimentally by his brother William.

It is hardly necessary, if indeed it were possible, to particularise the numerous brilliant papers with which Kelvin enriched the pages of the scientific journals of the day. The Royal Society of Edinburgh was the medium through which he published his researches on the Dynamical Theory of Heat, many of his hydrodynamical investigations, including his Vortex Atom papers, the dynamical basis of reflection, refraction and diffraction of light, gyrostatic action, atomic configurations and others besides. His close association with Tait and his long Presidency of the Royal Society of Edinburgh entitle him to a special place in Edinburgh's scientific roll of honour.

Balfour Stewart was a student both at St. Andrews and Edinburgh, and after some years spent in business, partly in Australia, he returned to Edinburgh and became assistant to Forbes in 1853. Here he made his researches on Radiant Heat, giving complete scientific precision to Prevost's Theory of Exchanges. His two important papers were read before the Royal Society of Edinburgh in the session 1857–58 (*Trans. R.S.E.*, xxii). He was the first to establish the existence of internal radiation in transparent substances like rock-salt and glass; and by means of apt experiments and faultless reasoning proved the great radiation law of the equality of radiation and absorption for all qualities of rays. Kirchhoff, a year later, presented similar proofs in more severe mathematical form; but it is now clearly recognised that Stewart's demonstrations are logically quite as sound. Some of Stewart's experiments are peculiarly beautiful, such, for example, as his proof that red glass when heated radiates a greenish tint, and green glass a reddish tint. Again, when red glass is at the same temperature as a glowing fire behind it, the glass appears transparent, since by its own radiation it compensates for what has been lost by absorption. If the glowing coal is at the higher temperature the glass will show reddish, but it will show greenish if the glass is at the higher temperature.

Another striking illustration given by Stewart was the radiation from heated tourmaline, which he showed to be polarised in the plane perpendicular to the plane of polarisation of transmitted light.

Closely connected with these researches is the whole theory of spectrum analysis, which was developed a little later in all its fullness by Bunsen and Kirchhoff. Edinburgh, however, claims a further share in the establishing of this far-reaching theory through the work of William Swan (1818–94), who was born and educated in Edinburgh and after some years spent as a teacher of science was appointed Professor of Natural Philosophy in St. Andrews. In his paper on *The Prismatic Spectra of the Flames of Compounds of Hydrogen and Carbon* (*Trans. R.S.E.*, xxi, 1857) he showed that a persistent yellow line was due to incandescent sodium. Swan's earlier paper on *The Gradual Production of Luminous Impressions on the Eye* *and other Phenomena of Vision* (*Trans. R.S.E.*, xvi, 1849) contains also new results of high interest, and ten years later in a second paper on the same subject (*Trans. R.S.E.*, xxi) he describes in detail his Prism Photometer, which is essentially the foundation of Lummer and Brodhun's photometer constructed thirty years later (see *Phil. Mag.*, xlix, 1900).

While still pursuing the line of investigation begun in Edinburgh, Balfour Stewart was appointed Director of Kew Observatory (1859–70). This opened a new field of work in terrestrial magnetism, sun-spot activity and meteorology generally, which he thenceforward cultivated with unceasing vigour. For the last seventeen years of his life he was Professor of Physics at Owens College, Manchester. Stewart was the author of several standard works, his admirable treatise on the *Conservation of Energy* being specially worthy of mention.

James Clerk Maxwell and Peter Guthrie Tait were schoolboys at the Edinburgh Academy. After one year's study at the University of Edinburgh, the latter pushed on to Cambridge, coming out finally as Senior Wrangler and First Smith's Prizeman. Maxwell, on the other hand, lingered two or three years at Edinburgh University before proceeding to the great centre of English mathematical life. Even as a schoolboy, "Dafty Maxwell," as he was nicknamed, had already published a mathematical paper in the *Proceedings of the Royal Society of Edinburgh* (vol. ii, 1846). It was an ingenious extension of the thread-and-foci method of describing the ellipse, and led to the discussion of a variety of other egg-shaped curves. Before leaving Edinburgh for Cambridge Maxwell communicated two other papers to the Royal Society, one on Rolling Curves and the other on the Equilibrium of Elastic Solids. These established his reputation as an original thinker. He was, in truth, a real and exceptional genius, as his great career subsequently disclosed. Edinburgh University claims him as one of her sons, for within her walls he worked and read and pondered over all types of human thought; and passed on to Cambridge with a vast amount of learning which the pedantic mathematical tutor regarded as useless lumber for one aiming at a high Wranglership.

The paper on Elasticity already referred to contained an account of how strain in quickly cooled glass could be studied by means of the behaviour of polarised light passed through the glass. The method has been recently developed in engineering testing by E. G. Coker, student and graduate of Edinburgh, now Professor of Civil Engineering in University College, London. Maxwell's other papers communicated to the Edinburgh Society deal with experiments on colour, a very original discussion of the motion of the top with suggestions as to the earth's motion, and the theory of reciprocal figures and force diagrams. All have had a permanent influence on scientific method and thought. His greatest contributions to science on such questions as Saturn's Rings, Kinetic Theory of Gases (in which he rediscovered Waterston's Law of Equipartition), and the all-embracing theory of the electromagnetic field of which he was the creator, were published elsewhere. Yet through the strenuous investigations of all too short a life Maxwell kept in close touch by correspondence with Tait in Edinburgh, from whom he received both ideas and criticism. This correspondence, sparkling with humour and fun and bright with serious science, will be found in C. G. Knott's *Life and Scientific Work of P. G. Tait* (1911). The direct results of Maxwell's grand comprehensive theory of electricity and light are, on the practical side, wireless telegraphy; on the theoretical side, the modern doctrine of Relativity. See also in this connection Whittaker's *History of the Theories of Æther and Electricity* (1910).

P. G. Tait succeeded Forbes in the Natural Philosophy Chair, and proved an able lecturer and a talented investigator. As official heir of the metal bars which Forbes used in his work on the conduction of heat, Tait followed out this research by constructing bars of other metals and measuring their conductivities by various methods. In this work he was assisted by several of his students, and especially by A. Crichton Mitchell, afterwards Director of Public Instruction in Travancore, and now head of the Scottish branch of the Meteorological Office. By his own later investigation on the law of cooling, Mitchell fully established Newton's Law, which is accurate as Newton gave it—namely, when the cooling is in a steady current of air. All critics, except Fourier, have neglected this qualification. Another fruitful line of work was suggested to Tait by Kelvin's theory of thermoelectricity. His discoveries of the curious discontinuities in thermoelectric power which characterised the magnetic metals, iron and nickel, are of deep theoretic interest. In testing the errors of the Deep Sea self-registering thermometers which had been used by Wyville Thomson and John Murray during the "Challenger" Expedition, Tait was led to utilise the hydraulic press supplied by the Admiralty for a great variety of investigations on the compressibility of solutions. Much of Tait's experimental work was carried out under his direct supervision by his laboratory students, of whom twenty-five became holders of scientific Chairs in other Universities and Colleges. In this way Edinburgh spread her scientific lore to the utmost ends of the earth.

Sir James Dewar, Professor of Natural Philosophy in Cambridge and of Chemistry in the Royal Institution, London, began his great career as a student in Edinburgh under Forbes, Tait and Lyon Playfair. While still in this city he discovered the use of charcoal in the production of high vacua and laid the foundations of his subsequent work on the liquefaction of gases, and the production of low temperatures. His vacuum flasks, used originally for storing liquid air, are now in universal use for preventing cooling as well as heating. Before leaving Edinburgh in 1874, Dewar had accomplished much valuable work in chemistry and physics both by himself and in conjunction with Tait and others. For example, he prepared the bars of sodium and potassium with platinum contacts fused through the containing glass tubes, with which Tait and his students determined the thermoelectric properties of these metals (*Proc. R.S.E.*, 1874). Tait and Dewar also established by ingenious experiments the true explanation of Crookes's Radiometer. (See *Tait's Life*, pp. 79–82.) Dewar's subsequent work is enormous and much of it epoch-making.

Sir J. Alfred Ewing, now Principal of Edinburgh University, also began his work as a physicist in Tait's Laboratory. He assisted Fleeming Jenkin, Professor of Engineering, in several researches, of which the analysis of vowel-sound records by means of the phonograph is worthy of mention (*Trans. R.S.E.*, xxviii, 1878). In Japan (1879–83) he carried out his well-known investigations on magnetic hysteresis (*Phil. Trans.*, 1884), and was the first to obtain by means of instruments of his own invention a record of the three components of an earthquake movement. His *Magnetic Induction in Iron and other Metals* remains a classic work on this important aspect of magnetic phenomena.

Others of Tait's students also found academic posts in Japan during the 'seventies and 'eighties, and the interest in seismology there aroused led to the publication of papers on seismic radiations and earthquake waves (*Proc. R.S.E.*, xxviii, 1907, and xxxix, 1918) and of *The Physics of Earthquake Phenomena* (Clarendon Press, 1908) by C. G. Knott.

In the last quarter of the nineteenth century, when Tait was general secretary of the Royal Society of Edinburgh, the meetings of that Society were of great interest, partly on account of the personalities of the resident Fellows, partly on account of the great scientific men who came within its walls. Kelvin frequently came through from Glasgow; and Charles Piazzi Smyth (1819–1900), the Astronomer Royal, with red fez on his head, gave from time to time in his extraordinary rhetorical manner his latest spectroscopic results. His micrometrical measurements of gaseous spectra and his visual solar spectrum (*Trans. R.S.E.*, xxxii, 1884) are illustrated by magnificent coloured plates of spectra of high dispersion arranged according to a scale expressing the number of wave-lengths to the inch. This unusual mode of representation has seriously diminished their usefulness for other investigators. It was also Piazzi Smyth who drew special attention to the predictive value of the rain-band in the yellow region of the solar spectrum; and this led to an interesting paper on the subject by Hugh Robert Mill (*Proc. R.S.E.*, 1882–83).

The rock thermometers on the Calton Hill installed by J. D. Forbes engaged Piazzi Smyth's close attention. He found indications of a cycle of change corresponding to the eleven-year cycle of sun-spots. On the meaning of the Great Pyramid and the sacredness of the English inch, Smyth was a sublime "paradoxer" in De Morgan's meaning of the term. His extraordinary style of composition is displayed in all his papers, but in none so appositely as in his picturesque obituary of Leverrier, the brilliant but intensely autocratic French Astronomer (*Proc. R.S.E.*, ix, 1877).

The year 1876 was famous for the invention of the modern telephone by Alexander Graham Bell, who was born at Edinburgh in 1847 and educated at the Royal High School. His father, Alexander Melville Bell, the author of a well-known work on *Visible Speech*, removed to London in 1865 and some years later settled in America along with his son, who devoted himself to the teaching of deaf mutes. The first Bell telephones ever heard in Edinburgh were made in Tait's Laboratory by two of his students; and the whole connected subject of telephones and microphones received great advances through the ingenious experiments of James Blyth, then mathematical master in George Watson's School and afterwards Professor of Natural Philosophy in the Royal Technical College of Glasgow (see *Proc. R.S.E.* from 1877 to 1882).

When Chrystal took up the work of the Mathematical Chair in 1879, there was no official summer session in the Arts Faculty. He was therefore able to devote the summer months to physical experimental work, which he carried out in Tait's Laboratory. Chrystal was full of fresh ideas and greatly stimulated the laboratory students. His own special work centred round his Differential Telephone, by means of which he measured induction coefficients in coils whose resistances were balanced in a Wheatstone Bridge. In later years, in connection with Sir John Murray's survey of the Scottish Lochs, he carried out a prolonged series of observations of seiches, and co-ordinated them with a beautifully worked-out mathematical theory. For this out-of-door work he commandeered the assistance of his ablest students, including E. Maclagan Wedderburn, to whom we owe the later investigation of the Temperature Seiche (*Trans. R.S.E.*, xli, xlv–xlviii, 1904–13). For these researches Chrystal was awarded a Royal Medal by the Royal Society of London. He had indeed all the instincts of the born experimenter. Unfortunately the increasing demands of the mathematical department and his work as Dean of the Faculty of Arts and as general secretary of the Royal Society of Edinburgh (in which post he succeeded Tait in 1901) gave him scant leisure for experimental work. His articles on "Electricity" and "Magnetism" contributed to the ninth edition of the *Encyclopædia Britannica* were masterly treatises and thoroughly up to date at the time of their publication; and his experimental verification of the truth of Ohm's Law for varying strengths of currents, carried out in the Cavendish Laboratory while he was still in Cambridge, ranks as a classical research, well planned and brilliantly executed (see *B.A. Report* for 1876).

So far only the more experimental side of Tait's activities has been touched upon. But Tait was also a strong mathematician and an accomplished writer of scientific books. When Professor of Mathematics in Belfast (1854–60) he was attracted to the study of Hamilton's quaternions as a calculus certain to be of value in physical applications. In his own treatise on the subject and in his numerous papers communicated to the Royal Society of Edinburgh, Tait developed certain aspects of quaternions with power and elegance—notably the linear vector function ϕ, and the differential operator ∇, which contains in its quaternion essence the special operators Grad, Div, and Curl. These names or contractions of names (gradient, divergence) were suggested by Maxwell after Tait had developed their properties in terms of the one quaternion symbol ∇, operating on scalar or vector. Tait also established in generalised form certain important relations connecting line, surface and volume integrals, some of which were rediscovered, long afterwards, by later writers and even named after them!

Among other subjects which engaged Tait's mathematical powers were the theory of brachistochrones, the phenomena of mirage, the theory of knots, the flight of the golf ball in air, and the Foundations of the Kinetic Theory of Gases. In this last series of papers, Tait set himself to examine the logic of the argument involved in the faulty and incomplete demonstrations given by Maxwell, Clausius and Boltzmann, especially in their earlier presentation of the basis of the theory. Tait's discovery of the fundamental importance of "underspin" in determining the length of drive of a golf ball and the accuracy of approach with well-played iron shots threw a new light on the whole process of play, and taught the intelligent player how to improve his game.

Tait enriched the literature of Natural Philosophy by a series of admirable text-books for the general student on Properties of Matter, Heat, and Light. His *Dynamics*, intended for more advanced mathematical students, is a succinct and yet complete exposition of the Newtonian philosophy as regards motion of particles, of rigid bodies, of fluids and elastic solids. His *Recent Advances in Physical Science* (1876) embodies a course of lectures given in 1874 to a "number of his friends—chiefly professional men"—who wished to know what had been recently discovered in such subjects as heat, atomic structure of matter, radiation, spectrum analysis, properties of light and the great doctrine of the conservation of energy. The book powerfully stimulated interest in physical science, as did also *The Unseen Universe or Physical Speculations on a Future State* (1875) written in conjunction with Balfour Stewart.

Thomson and Tait's *Natural Philosophy*, as originally conceived by Tait, was intended to be a complete mathematical and experimental treatise on the whole range of physical science. The genesis and growth of the book (it never got beyond volume i) are fully detailed in Tait's *Life* already referred to. Even this first volume would never have been completed if it had not been for the never-flagging determination on Tait's part to force Kelvin to do his share of the work, and to see the book through. For this the world at large is deeply indebted to Tait of Edinburgh.

Early in his career Tait expressed the hope that the large subject of Natural Philosophy would be ere long represented by two Chairs. The first step towards this goal was made in 1892, when the Lectureship in Applied Mathematics was established to take over the more mathematical side of Natural Philosophy. Since Tait's death in 1901 the whole department of Physics has been greatly developed, first by J. G. MacGregor, and then by the present professor, C. G. Barkla, who was awarded a Nobel Prize for his important work on X-rays and characteristic radiations. When the new "Tait Chair" of Natural Philosophy is established we may well expect Edinburgh to take an even greater lead in days to come than she has done in the past.

C. G. K.

ASTRONOMY

Definite astronomical work of a scientific character was not accomplished in Edinburgh till the time of Thomas Henderson (1798–1844), a native of Dundee. Apprenticed to a legal firm in Edinburgh, Henderson became in due course secretary to the Lord Advocate Jeffrey. His innate taste for astronomy showed itself in making him proficient in all types of astronomical calculation as well as in study. The models of method shown in Bessel's writings were his especial delight, and Henderson always regarded Bessel as his master. His legal duties carried him to London each year, and there he became acquainted with the inspiring group that was then building up the Royal Astronomical Society. His value was quickly appreciated. In an unselfish disinterested way that marked all his actions he contributed for several years computations of occultations and other phenomena to the *Nautical Almanac.* He wished to embrace astronomy as a profession, and in 1832 he went to the Cape of Good Hope in charge of the Observatory there. The place was ill-equipped, wild and remote, and was a heavy strain on a man of Henderson's gentle, social tastes. He remained there for only one year, but brought back with him a great mass of observations which he reduced and published in subsequent years.

In 1834 he was appointed Professor of Astronomy in Edinburgh University, and by the same commission Astronomer Royal for Scotland, with charge of the Observatory on the Calton Hill. This was an observatory founded in 1818 by a private association, the Edinburgh Astronomical Institution. Its upkeep was now undertaken by H.M. Office of Works, but at that date, and indeed up to the year 1889, when the Association terminated, its equipment was meagre and defective. Henderson, however, worked assiduously with the material at his disposal, and published numerous volumes of his observations.

The most notable outcome of the reduction of Henderson's Cape observations was the parallax of α Centauri, the first real determination of the distance of any star. Rapid motion, combined with great brilliance, singled this star out for examination. But a number of illusory results in other cases had made astronomers very sceptical. Henderson shared this caution to the full. He discussed his measures from three separate aspects, and showed that each gave a positive indication that could not be attributed to error. Even when this was done, determinations with the meridian circle had become so discredited that the best judges waited for further confirmation. Henderson had made these observations in 1833, but did not publish them till 1839. In publication he was anticipated by Bessel, who in the previous year had given irrefragable evidence of parallax in the star 61 Cygni. There is no reason to think that this anticipation was a source of chagrin to Henderson. Bessel's friendship was his delight and boast. In his science he regarded Bessel as his model, and he was no unworthy student of so great a master; in the field that his ability and opportunities laid open to him, his competence was complete. Personally Henderson was one of the most disinterested and amiable of men.

The Astronomical Observatories of Edinburgh deserve description. After the resignation of Piazzi Smyth in 1888, a transformation took place. The late Earl of Crawford, who had amassed a magnificent collection of instruments and books at his private observatory at Dunecht, was planning a new site for them at his home at Balcarres, but instead he made a gift of them to the nation. The astronomer at Dunecht, Ralph Copeland, was appointed successor to Piazzi Smyth; and the new Royal Observatory was shortly after built upon the Blackford Hill, on the southern outskirts of the city. Here the Dunecht instruments and books were housed in a permanent national establishment. The Crawford Library is almost unequalled in the completeness of its collection of old astronomical books; its series of early calendars and of works upon comets are particularly rich. It contains besides many manuscripts.

At the same date the Observatory upon the Calton Hill, which for many reasons had become ill suited for prosecuting exact astronomy, was taken in charge by the City, and has since been maintained for the benefit and pleasure of citizens, thus fulfilling the object for which the Astronomical Institution designed it.

R. A. S.

ACTUARIAL SCIENCE

Actuarial Science, which may be described briefly as dealing with problems involving the theories of compound interest and of probability, or either of them, finds its chief applications in the business of Life Assurance and Annuities, Widows' Funds, Pension or Superannuation Funds, etc. The formation of several Life Assurance Companies in Edinburgh about a hundred years ago, followed by a rapid increase in their business, necessitated an increasing number of actuaries to deal with such questions as the rates of premium to be charged and the valuation of the liabilities under the ever-increasing number of policies. The men who were responsible for the foundation and subsequent management of these early Scottish Companies naturally fell into the habit of consulting together to discuss the many novel and difficult problems which confronted them, and ultimately formed an Association of Managers. In 1848 one of them — William Thomas Thomson (1813–83), Manager of the Standard Life Assurance Co.—suggested to certain members of the Insurance profession in London that an Association might be formed embracing officials of companies throughout Great Britain. This suggestion ultimately led to the formation of the Institute of Actuaries in London, and in 1856 the Scottish members formed a separate Association in Edinburgh under the title of the Faculty of Actuaries in Scotland. Both the Institute and the

Faculty of Actuaries are purely scientific bodies with educative functions and power to make their membership a guarantee of professional standing and attainment. They hold examinations and issue diplomas of proficiency in Actuarial Science ; they have periodical meetings for the discussion and investigation of problems connected with Actuarial Science ; they give courses of lectures therein ; they publish *Transactions* which contain a record of practically every advance which has been made by successive generations of workers ; and they have undertaken various important investigations into the rates of mortality prevailing among assured lives and annuitants. The first contributor to the Edinburgh *Transactions* was James Meikle (1825–1904), Actuary of the Scottish Provident Institution, whose son is now Actuary to the Government of India. His name is gratefully remembered by many living actuaries on account of his masterly explanation of many of the fundamental formulæ in common use. He gave verbal interpretations thereof in place of the cumbrous analytical processes by which they were usually derived, and his method was not only easier for the student to follow but gave a clearer insight into the true nature of the functions dealt with.

Probably the greatest contributions to Actuarial Science were made by Dr Thomas Bond Sprague (1830–1920), Manager of the Scottish Equitable Life Assurance Society, whose original works are spread over many volumes of the *Transactions* of the Institute and the Faculty of Actuaries, and cover almost every branch of the subject. His investigations into the theory and his practical work on the statistical side have contributed more to the development of Actuarial Science than those of any other, and his name will be known for long in connection with (for example) his researches into the effect of medical selection upon the rates of mortality of insured lives. It had been long known that these depended not merely upon the age but also to some extent upon the length of time for which the life has been insured, but he was the first to furnish a measure of its effect and to develop the theory from which reliable numerical measures of the varying rate of mortality can be obtained. His investigations into rates of marriage among bachelors and widowers and the probability of issue form the basis upon which such contingencies are valued at the present time, and his theoretical work on such subjects as notation, osculatory interpolation and graduation (to name only a few out of many) may be regarded as the basis on which the existing methods have been reared as a superstructure.

Another Fellow of the Faculty whose name is a household word among the profession throughout the world is Mr George King, whose works have for a generation or more formed the standard text-books on the subject, and to whom all living actuaries owe a deep debt of gratitude for laying out a smooth path from the elements up to some of the most complex developments of the science. His services with regard to actuarial theory may be compared to those of Euclid in respect of geometry, in that he has constructed from a mass of disconnected propositions a logical and systematic text-book, which after nearly forty years is still without a rival and is in daily use in all the five continents.

It was a suggestion of a member of the Faculty of Actuaries that led to the University of Edinburgh recently instituting its diploma in Actuarial Mathematics—a step which seems likely to have far-reaching effects upon the future development of the science; and other evidences of the influence of the Faculty are to be seen in every continent and almost in every important country. Its Fellows hold important positions not only in England and in Scotland, but India, China, Africa, Australia, Canada and the Americas.

As an indication of the importance of Actuarial Science in Edinburgh it may be mentioned that the Life Assurance and Annuity Funds of companies with headquarters in the city exceed £100,000,000.

A. E. S.

Meteorology

The first volume of the *Transactions of the Royal Society of Edinburgh* (1783–85) is notable in the history of Meteorology for two papers in it—Hutton's paper on *The Theory of Rain*, and that by Professor Patrick Wilson of Glasgow, on *Hoar Frost*. Hutton's theory, inadequate as it was, since the mere mixture of currents of air of different temperatures can produce only trifling precipitation, indicated a definite movement towards the truth and an appreciation of the fact that rain is due somehow to the cooling of great masses of air. Wilson's paper, on the other hand, excellent in itself, is noteworthy as having inspired much of the work of Charles Wells, himself of Scottish parentage, and a graduate in Medicine of Edinburgh University (1780), though his fortunes took him to London, where his *Essay on Dew* was published in 1814.

From those distant days until the present time the publications of the Royal Society of Edinburgh have contained many papers of meteorological interest, and we may for convenience take *Trans. R.S.E.*, vol. xxii (1857–61), as marking a definite stage in the history of the science. In earlier volumes we find contributions from Playfair, Leslie, Rutherford, Keith, Scoresby, Davy, Rankine, and others; two by Brewster; and several by James D. Forbes. In volume xxii we find Thomson (Lord Kelvin) and Everett discussing the method of dealing with the underground temperatures recorded by the thermometers installed by Forbes (p. 19). Forbes himself contributed a classic memoir on *The Climate of Edinburgh* and a substantial paper entitled *Inquiries about Terrestrial Temperature*, both influenced to some extent by the speculations of Dove and the statistical methods of Quetelet.

Already, in 1855, the Scottish Meteorological Society had been founded, mainly through the exertions of two men—Sir John Stuart Forbes of Pitsligo and Fettercairn, Bart., the elder brother of J. D. Forbes, and David Milne Home of Wedderburn and Milne Graden, a distinguished geologist and notable for a controversy with Charles Darwin. The time was altogether ripe for the foundation of such a society in Scotland. The work of Dove in Berlin, of Leverrier in Paris, and of Redfield, Espy and Maury in America had aroused world-wide interest amongst men of science. In Scotland itself much excellent observational work had been done by Sir Thomas Makdougall Brisbane and John Allan Broun at Makerstoun in Roxburghshire (see p. 20); by Arthur Forbes of Culloden; by the Duke of Richmond and Gordon at Gordon Castle; and by many less well-known workers. And there was the example of London, where in 1850 a society had been formed that was to develop into the Royal Meteorological Society.

The story of the early days of the Scottish Meteorological Society has been fully told and is rich in interest. With Sir J. S. Forbes and Milne Home were many men of the highest social and professional standing—the eighth Marquess of Tweeddale, soldier, statesman and scientist; Alexander Keith Johnston, a geographer of international reputation; Thomas Stevenson, the famous lighthouse engineer; Sir (then Dr) Arthur Mitchell; and others. In the Scotland of the middle of last century it was not difficult to secure financial support for an enterprise that appealed to an intelligent patriotism; but with all the vigour of its founders, one of the principal aims of the Society—the organisation of an adequate system of observations over the Scottish area—might not have been so speedily achieved, but for the practically independent action of Dr James Stark, who had been appointed Superintendent of Statistics in the newly-established Department of the Registrar-General for Scotland. Stark was a man of great originality and energy, and the pioneer in Scotland of the science of vital statistics. For some two or three years he acted as Secretary of the Society, followed for brief periods by J. D. Everett and A. H. Burgess.

In December 1860 a new appointment was made, and in the light of later history the report of the Council announcing the selection of "Mr. Alexander Buchan, teacher, Dunblane," and expressing the hope that he would be found well qualified for the office of Secretary, reads somewhat quaintly.

For nearly half a century the history of Scottish meteorology centres round Dr Buchan (1829–1907). Already distinguished as a botanist, he speedily familiarised himself with what had previously been done in meteorology, and his *Handy Book* remains an indispensable companion. The long tale of original high-class work standing to his credit is amazing, and cannot here be told in full. Hann has described the paper on *The Mean Pressure of the Atmosphere and the Prevailing Winds of the Globe* (*Trans. R.S.E.*, xxv, 1869) as epoch-making, and as sufficient alone to secure for the author "a foremost place among meteorologists of all ages." In Europe generally Dove's preconceived theoretical ideas reigned almost supreme; but Buchan's work was based on the sure ground of a study of synchronous observations of weather phenomena, and drove home the truth that it is the distribution of pressure that determines the winds. The general acceptance of Buys Ballot's Law was largely due to him, and he was the first to demonstrate from actual observations the dominating influence over the weather of North-Western Europe of pressure conditions in the Icelandic region. Throughout his life rainfall and climatological problems absorbed much of his attention; his work along with Sir Arthur Mitchell on the Influence of Weather on Mortality indicated a field that awaits further exploration; the "*Challenger*" *Report on Atmospheric Circulation* (1889) would have conferred distinction on a well-staffed Government Office, yet he had but little help in its preparation, save from his devoted niece, Miss J. H. Buchan; and much of his personal work was incorporated in Bartholomew's magnificent *Atlas of Meteorology* (Edinburgh, 1899).

During his later years he was absorbed in the work of the Ben Nevis Observatories.

Buchan was for nearly half a century a great figure in Edinburgh life. He was fortunate in his friends, as they were in him, and notable tributes have been paid to his memory by Sir Arthur Mitchell, M'Kendrick, Murray and others. A long procession of workers fell under his influence — amongst them Robert Louis Stevenson, who published a paper on *The Thermal Influence of Forests* (*Proc. R.S.E.*, viii, 1873).

In the early eighties of last century the scientific spirit in Scotland was greatly stimulated by two events, the concentration in Edinburgh of the preparation of the *Challenger Reports* under the direction of Sir John Murray, and the establishment of an observatory on the summit of Ben Nevis. Himself in the front rank of science, Murray (1841–1914) had a wonderful power of inspiring younger men, and in those days we find H. R. Mill associated with him in Edinburgh, and twenty years later E. M. Wedderburn concerned with "seiches" and the influence of wind on water.

The whole Ben Nevis enterprise was a formidable one, and but for Murray's driving power financial difficulties could hardly have been overcome. Anxieties were constant, Government support was inconsiderable, and the Scottish public by practically maintaining an observatory on the summit of the mountain for twenty-two years (1883–1904), and another at the foot for fifteen years (1890–1904), rendered a service to science of which they may be justly proud. On the administrative and scientific side success was due primarily to the self-sacrificing labours of the late Dr R. T. Omond (1858–1914). Fresh from Tait's laboratory, where he had worked with his great master at the famous "big gun" experiments that determined the proper corrections to be applied to the "Challenger" deep-sea thermometer, Omond faced the climatic and physical difficulties of life on "The Ben" splendidly. Routine work was heavy, yet his mind was always fresh, and always he was the natural philosopher. With health seriously impaired, he withdrew to Edinburgh in 1895, though not to inactivity. For long he was in almost constant attendance at the rooms of the Scottish Meteorological Society, in close companionship with Buchan and mainly absorbed in preparing for publication and passing through the press the last three of the four substantial volumes of the *Transactions of the Royal Society of Edinburgh* that contain the full record of the Ben Nevis Observatory. Omond's numerous scientific papers and reports were prepared with admirable care : nothing but the best way of putting a thing was ever good enough for him. His friends bear in affectionate remembrance his generous mind, his humour and his unfailing courage.

Much might be written about the Ben Nevis work, but the record is accessible. From first to last Angus Rankin was a tower of strength on the staff : he succeeded Omond as Superintendent, and has since 1904 been in the meteorological service of the Argentine Republic. Men of distinction took a share in the direction ; a simple "stephanome" by Tait was in constant use, and experiments were for a time made with his "atmometer" ; but snow and fog-crystals proved too much for an anemometer designed by Chrystal. Great service was also voluntarily rendered by enthusiastic observers, notably by H. N. Dickson ; by the late A. J. Herbertson, whose researches in hygrometry are valuable ; by R. C. Mossman on many occasions ; by W. S. Bruce ; and by W. T. Kilgour, whose book, *Twenty Years on Ben Nevis*, is excellent from the popular standpoint. Throughout, a Committee reported each year to the British Association. The scientific significance of the whole enterprise has been indicated in a masterly way by Hann (*Journal Royal Met. Soc.*, xxxviii, 1912).

The first communication of John Aitken (1839–1919) to the Royal Society of Edinburgh was made as long ago as 1875, and his latest, posthumously, within the past year. His great paper on *Dust, Fogs and Clouds* (*Trans. R.S.E.*, xxx, 1881), and his later papers on Cloudy Condensation are of capital importance in meteorology; and he made many investigations under varying conditions with his own Dust-counter. Following on C. T. R. Wilson's discovery that ionised air, even if dust-free, produces cloudy condensation if vigorously cooled by expansion, there has been an inclination to underestimate the importance of the part played by dust particles in the condensation of water vapour from the atmosphere; but, as Knott pointed out, Aitken's work stands firm, since the sudden expansion and cooling required to produce cloudy condensation on ions in dustless air are greater than can ever occur in nature. Again, the paper *On Dew* (*Trans. R.S.E.*, xxiii, 1885) is memorable, with its demonstration from observation and experiment that the vapour which condenses on cold surfaces on nights when terrestrial radiation is active comes mainly from the ground below, and not from the air above. Apart from his greatest papers, one marvels at the fertility of Aitken's mind and the great variety of subjects he experimented on. Thus one of his more recent communications was on the *Evaporation of Musk and other Odorous Substances* (1905), and one of his earliest (1877) on *Ocean Circulation*. It will be interesting to see whether the final challenge of his posthumous paper on *Thermometer Screens* (1921) will be taken up: he had long contended that the ordinary "Stevenson Screen" was an inefficient protection from the effects of radiation, direct and indirect. A collected edition of his more important papers is to be published by the Royal Society of Edinburgh.

The services to meteorology of R. C. Mossman extend over more than thirty years and have been many and varied. He discussed various aspects of the Ben Nevis work, and his independent enterprise in Glen Nevis during the winter of 1901–2 resulted in a valuable contribution to topographical meteorology. Attracted by the earlier work of J. D. Forbes, he collected all that was on record about the weather of his native city, and his three memoirs on *The Meteorology of Edinburgh* are a monument of industry, patience and good judgement (*Trans. R.S.E.*, xxxviii–xl, 1895–1902). His meteorological papers are very numerous. Well equipped not only in meteorological but in magnetic work, Mossman accompanied the "Scotia" Expedition (1902–4) to the Antarctic and himself discussed the results in an admirable manner. After the return of Dr Bruce's expedition, he remained for a second year at the station on Laurie Island in the South Orkneys. He is now in the service of the Argentine Republic, and has worked out some remarkable relationships between temperature conditions in the Antarctic and the subsequent rainfall in the Argentine.

One cannot here even enumerate the many workers who have done good service to meteorology in Scotland. On the observational side a short series of records in Edinburgh is available at as distant a date as 1731, and those by Alexander Adie between 1795 and 1850 are very valuable. On the side of research, we have, for example, J. Y. Buchanan's paper on *The Meteorology of Ben Nevis in Clear and Cloudy Weather* (*Trans. R.S.E.*, xxxix, 1899), and that by Knott on *Solar Radiation and Earth Temperature* (*Proc. R.S.E.*, xxiii, 1901). And, recently, we have had Franklin's investigations of soil temperatures, and C. K. M. Douglas's remarkable work on the structure of clouds, illustrated by beautiful photographs taken from an aeroplane.

Mr Andrew Watt had been appointed assistant to Dr Buchan in 1900, succeeded him in 1907, and remained Secretary to the Society till 1921. He edited the *Journal*, and contributed to its pages various studies of rainfall and other problems and many notes. His paper on *The Early Days of the Society* is of historical interest (*Journal Scot. Met. Soc.*, Third Series, No. 28).

These are but brief notes, but the story of meteorology in Scotland may be found in full in the *Journal of the Scottish Meteorological Society*. That Society commenced its useful career with the benediction of the British Association which met in Glasgow in 1855; and now, in 1921, on amalgamation with the Royal Meteorological Society, the familiar name has disappeared. A retrospect suggests many reflections, and the chief is this. Scotland has always been conspicuous for the great services rendered to science by the amateur as distinct from the professional worker, and now that recent developments have secured the future of official meteorology in Scotland it is to be hoped that there will still be room for the independent worker. Not otherwise can the memory of the great men who have gone be fully honoured.

A. W.

II

CHEMISTRY

Pure Chemistry—Industrial Chemistry—The Scottish Shale Oil Industry

PURE CHEMISTRY

IN connection with the development of pure chemistry, Edinburgh is amply justified in laying claim to a distinguished position, on the single ground of having been the scene of the investigations of Joseph Black (1728–99), who will always be remembered by chemists as the discoverer of " fixed air " (carbon dioxide) and of the true nature of the difference between the so-called " mild " and " caustic " alkalies (alkali metal and alkaline-earth metal carbonates and hydroxides). These extremely important discoveries of Black bring Edinburgh into the closest association with one of the more remarkable turning-points in the progress of chemistry, and with the introduction of views which may certainly be regarded as having assisted, in an indirect manner, at least, if not perhaps to some extent directly also, in the overthrow of the then all but universally accepted phlogiston theory of combustion. Although they are by far the most prominent, they are, however, as will be shown later, by no means the only contributions with which Edinburgh is connected, in relation to subjects that have attained more than ordinary importance in the history of chemistry.

Chemical progress in Edinburgh has centred mainly, although not exclusively, in the University Chair of

Chemistry[1] and Chemical Laboratories which, since the middle of the eighteenth century, have been occupied and presided over by a succession of professors whose names are famous all over the world.

The first of these professors who need be mentioned is William Cullen, the eminent physician, who was appointed to the Chair in 1755. While Cullen did not himself make any chemical discoveries of a specially prominent description, his title to mention here rests upon the fact that he was amongst the first to recognise the high importance of scientific chemistry and to advocate its application in medicine and in agriculture, as well as in the arts and manufactures. Various chemical investigations which he made himself, or which he instigated, had for their object the providing, from home resources, of wood ash to be employed instead of ashes imported from Russia and elsewhere, in the bleaching of linen, and, further, the improvement of the processes of linen bleaching as these were at that time carried out in Scotland, prior to the introduction of the art of bleaching by the aid of hypochlorites.

It is not improbable that the extreme value attached by Cullen to the advancement of chemistry as applied to medicine was in great measure responsible for the investigation of the nature of *Magnesia alba* and quicklime, undertaken by his pupil, Black, which led, in the hands of the latter, to the elucidation of the relationship of the mild to the caustic alkalies.

Joseph Black (1728–99) became Professor of Chemistry and Medicine in 1766. After his school education, which seems to have been chiefly in Belfast, he entered the University of Glasgow in 1746 and soon attracted the attention of Cullen, who, as a Professor of Medicine and Lecturer on Chemistry there, began his first course of lectures on the latter subject in 1747. Black was an ardent student and lover of chemistry, and there sprang up a friendship between him and Cullen which was something more than that which marks the relation of pupil and teacher, and was maintained by familiar and intimate correspondence upon chemical and other subjects after the former had proceeded to Edinburgh in 1750 to continue his medical studies.

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[1] Until 1844 this Chair was filled by a Professor of Chemistry and Medicine.

It is from this Edinburgh period that Black's classical investigation upon alkaline substances dates. His experiments were carried out about 1752–53 and his results were first published in 1754, in his thesis for the Degree of M.D. This thesis was written in Latin, in accordance with the usage of the period, and was entitled *De humore acido a cribis orto, et magnesia alba.* A fuller account of the experiments, in English, under the title *Experiments upon Magnesia Alba, Quicklime, and some other Alcaline Substances*, was read in the following year and was published in the second volume of the *Essays and Observations, Physical and Literary* (see page 8).

Black informs us in the latter publication that he was "led to this examination of the absorbent earths, partly by the hope of discovering a new sort of lime and lime-water, which might possibly be a more powerful solvent of the stone than that commonly used." In this hope he was disappointed, but he made instead a discovery which he had not set out to look for. The story of this great research has often been told, with more or less detail,[1] and only a general reference to the most important results need be introduced here.

Stated in the usual terminology of the period, Black showed that by the expulsion of "fixed air" from crude calcareous earth (limestone) this was changed into quicklime, and that by the action of slaked lime (prepared from this quicklime) upon the mild alkalies, these were in turn rendered caustic by the transference of their fixed air to the slaked lime, whereby the latter again became mild. The quantity of an acid required to generate a salt from a given weight of limestone was found to be the same (and the same salt was formed) whether the limestone had or had not been changed into quicklime by heating, but in the former case it dissolved without the effervescence (due to the escape of fixed air) which was noted in the latter case. *Magnesia alba* (basic magnesium carbonate) and the *magnesia usta* (magnesium oxide) obtained from it by calcination exhibited the same features in this connection as limestone and quicklime respectively.

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[1] See Black's *Lectures*, edited by Robison, vol. i, 1803; Thomson's *History of Chemistry*, vol. i, 1830; Ramsay's *Gases of the Atmosphere*, 1896, and his *Life and Letters of Joseph Black*, 1918; Tilden's *Famous Chemists*, 1921.

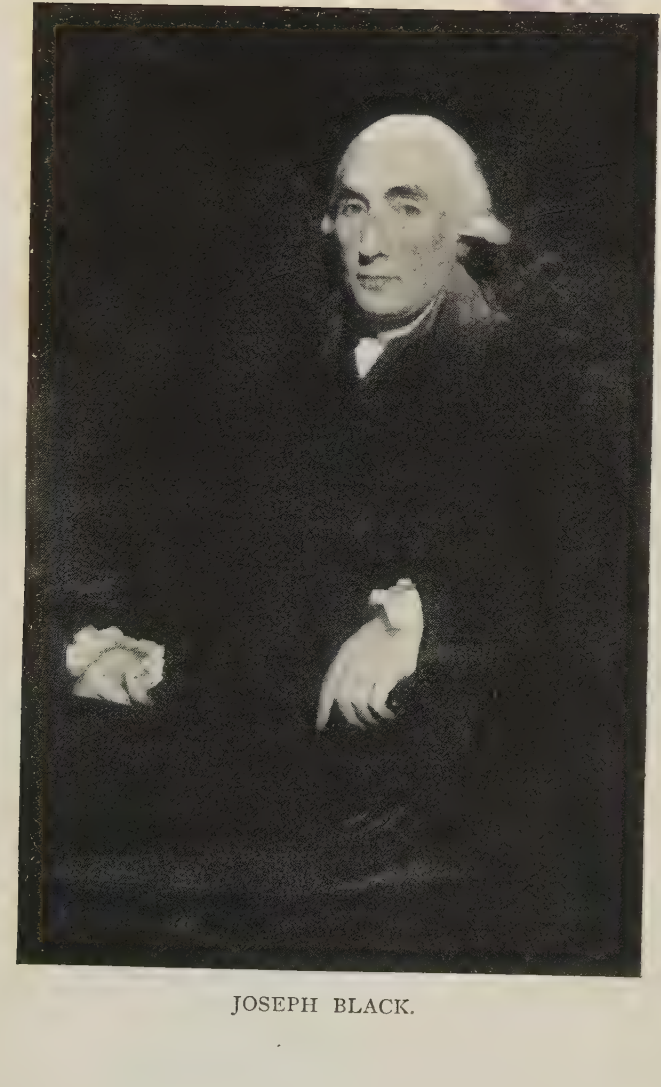
There is one point connected with Black's whole investigation which is of such special importance that it deserves to be re-emphasised. Black is here found constantly employing the balance, and basing his conclusions upon the results of quantitative experiments, carefully devised and skilfully carried out. In thus consistently determining the relationships by weight of the materials concerned when chemical changes occur, he may justly be regarded as a pioneer and to have provided an example which Lavoisier, a few years later, was prompt in imitating.

It may be noted that Black at first held the view current prior to his time with respect to the difference between the caustic and the mild alkalies, namely, that the former owed their caustic character to the presence in them of igneous matter, derived from the fire in the process of converting limestone into quicklime. This view was soon dispelled, however, by his own quantitative experiments, from which it appeared that, far from gaining anything material from the fire, the limestone sustained a substantial loss (amounting to nearly one-half of its original weight) owing to the escape of the gas which he named "fixed air" (carbon dioxide) because he regarded it as fixed or held in the limestone.

It appears somewhat remarkable at the present day to learn from his thesis that Black seems to have entertained doubts as to the suitability of the account of his experiments as a thesis for a doctor's degree in medicine. In the opening paragraph he remarks: "As I was thinking of this, my first little inaugural work, *Magnesia alba* spontaneously presented itself, and the subject pleased me, chiefly because its simplicity makes it more easily adaptable to the prescribed limits, and more suited to my powers. But when I considered what I had written on it, it did not seem to have such a relation to medicine as the motive of the work required, and I accordingly decided to preface it with some notes, as short as possible, on the acid humour derived from food, for which alone magnesia serves as a remedy." That he did not entertain any unduly high estimate of the value of his research as a whole is made sufficiently manifest by the following quotation from a letter which he wrote to Cullen from Edinburgh under date June 18, 1754: "I sent you . . . a dozen copies of my Thesis, which you will find to be less altered from the sketch you saw before than you expected. The truth is, I was quite tired of it before I gave it out of my hands. . . . What do you think of printing the experimental part in the Physical Essays here? If the experiments are worth anything they will be stolen by others; but yet I would rather have it so than make them public unless you think it would be of some sort of service to me."

Although trained in the phlogistic views of the period, Black was not a pronounced advocate of them, and in the English account of his experiments on alkaline substances there occurs only a single expression in which his adherence to them is recognisable. This is at the place where, treating of the preparation of the volatile alkali (ammonia) in a caustic form, he refers to the preparation by Margraaf of "an ammoniacal salt, *the acid of which is the basis of the phosphorus*." He was one of the earliest adherents in Britain to the "antiphlogistic" theory of combustion advanced by Lavoisier.

For Black's investigations in latent heat, see above, page 9.



JOSEPH BLACK.

The next notable advance in chemistry with which Edinburgh is intimately connected relates to the recognition of nitrogen as a separate constituent of the atmosphere. This subject also formed the material for a thesis which was submitted to the University for the degree of M.D. by Daniel Rutherford in 1772. This Daniel Rutherford (1749–1819) was a native of Edinburgh, and the son of Dr John Rutherford, one of the Founders of the Edinburgh Medical School and Professor of Medicine in the University. Dr John Rutherford was the maternal grandfather of Sir Walter Scott. Dr Daniel Rutherford practised as a physician in Edinburgh, and was appointed to the University Chair of Medicine and Botany in 1786. He is stated to have been more eminent as a physician than as a botanist. Andrew Lang in his book on *Sir Walter Scott* somewhat playfully remarks regarding him: "Scott's maternal uncle, Dr Rutherford, 'was one of the best chemists in Europe'—we have Sir Walter's word for it."

Rutherford's thesis is entitled *De aere fixo dicto, aut mephitico*. In it he first deals at some length with Black's fixed air, which he uniformly calls mephitic air, but, so far as this air is concerned, he does not adduce much that was not already known. He then proceeds to discuss the effect upon a confined portion of air, of animal respiration, followed by the removal of the mephitic air produced thereby. He states that "by the respiration of animals, wholesome and good air not only becomes mephitic, but it also suffers another singular change. For, after all the mephitic air has been separated and removed from it by means of caustic lye, still what remains does not become in any way more wholesome; for although it produces no precipitate in lime-water, it extinguishes both flame and life no less than before."

With respect to combustion he says: "As the effects are nearly the same, what I have brought forward as to respiration may be repeated as to combustion"; and later, where he states that "we may conclude" that "the malignant air" remaining after these processes of respiration and combustion "is composed of atmospheric air united with phlogiston" (in modern language, deprived of its oxygen), he adds that "this is confirmed by the fact that air which has just served for the calcination of metals, and has taken phlogiston from them, is obviously of the same kind."

It is upon the short portions of his thesis here quoted that the title of Rutherford to be regarded as the discoverer of nitrogen rests. In his experiments he evidently obtained residues from atmospheric air which were free from carbon dioxide, but which contained so little oxygen as to be unfit to support respiration or combustion. When he burned phosphorus in confined air, he probably obtained residues free from anything more than a trifling proportion of oxygen, and the calcination of metals may have given almost the same result. It can scarcely be claimed, however, that his experiments went far towards characterising these residues more particularly than as non-inflammable and non-supporters of respiration and combustion.

In 1795, Thomas Charles Hope (1766–84), a native of Edinburgh and a medical graduate of the University, was appointed, in consequence of Black's failing health, to act as joint Professor of Chemistry along with the latter, and on Black's death in 1799 he became sole Professor. As Professor of Medicine in the University of Glasgow he had already made a careful examination of a large number of strontium compounds. In 1793 he communicated his results in a paper to the Royal Society of Edinburgh, entitled *An Account of a Mineral from Strontian, and of a Peculiar Species of Earth which it contains,* in which he announced the discovery of a new "earth." This announcement he had already made in a communication to the Glasgow College Literary Society in March 1792, as the result of experiments made in 1791–92, whereby Klaproth, who also investigated the mineral, was anticipated in the recognition of strontia as different from baryta. For Hope's physical work, see page 14.

In the earlier years of the nineteenth century, marked divergence of opinion still existed regarding the true nature of chlorine (or oxymuriatic acid, as it was then called), and it was in Edinburgh that the greater part of the "chlorine controversy" as carried on in Great Britain centred. The questions at issue were whether oxymuriatic acid (chlorine) was an elementary substance, as held by Sir Humphry Davy after 1810, or the compound of an unknown basis with oxygen, as was then pretty generally, although not universally, held; and whether or not muriatic acid (hydrochloric acid) contained water. The older view was warmly supported in Britain by Dr John Murray, a lecturer in Edinburgh on natural philosophy, chemistry, materia medica and pharmacy, while the new view of Davy was as strongly advocated by his brother, Dr John Davy, whose experiments were conducted partly in London, in conjunction with Sir Humphry, and partly also in Edinburgh in Hope's laboratory in the University.

There are probably few chemists who take the trouble to read the letters containing the arguments and the accounts of the experiments of the British opponents in the chlorine controversy,[1] and yet these are not unworthy of perusal even now, more than a hundred years after the nearly universal acceptance of Davy's views, since Murray's letters show very clearly how, in absence of any complete proof of the one view or of the other, the experiments of the Davys might be explained upon either. The weak points of the older views were, of course, that no one had been able on the one hand to isolate the basis supposed to be united with oxygen in oxymuriatic acid, or, on the other, to prove the presence of water in dry muriatic acid gas or to produce it from the latter unless by interaction with some substance capable of yielding oxygen.

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[1] Nicholson's *Journal*, vols. xxviii–xxxii and vol. xxxiv (1811–13).

Eventually the controversy became narrowed down to the recognition by the opponents that if dry ammonia gas united with dry muriatic acid gas without the separation of water, the question would be virtually settled in favour of the views of the Davys. The experiment was tried, separately, by the two, in the presence of scientific witnesses, of whom Hope was one in both instances, and the results obtained did not greatly differ. Murray observed the deposition of a small quantity of water, which he regarded as evidence in favour of his view. John Davy's experiment was made in the University Laboratory, and in it the deposition of a barely perceptible dew took place, which was regarded by him as most likely to be referred to a minute quantity of vapour in the gases.

It does not appear that Murray ever admitted the validity of the new views, but these were gradually adopted more or less generally by others, as the result of a variety of circumstances, such as the discovery of iodine and the examination of its compounds.

A point of special interest to be noted in connection with John Davy's experiments bearing upon the chlorine controversy is that in exposing mixtures of chlorine and carbon monoxide to sunlight he observed for the first time the formation of phosgene, and was led to an examination of that interesting substance.

The next two occupants of the University Chair of Chemistry after Hope—Dr William Gregory (1803–58) and Dr Lyon Playfair, afterwards Lord Playfair (1818–98)—were both intimately connected with the translating and editing of the numerous important books written by Liebig towards the middle of last century and later, which included his *Chemistry in its Applications to Agriculture and Physiology*, his *Animal Chemistry*, his *Familiar Letters on Chemistry*, his *Principles of Agricultural Chemistry* and others. Playfair's most important contributions to chemistry were an investigation of the gases of the blast furnace carried out in conjunction with Bunsen in 1845, and his discovery of the nitroprussides, which he obtained in 1849 by the action of nitric acid on the ferrocyanides. Both of these investigations were carried out prior to his election to the Chair in 1858. Playfair kept up a correspondence for many years with Liebig, but it does not appear that Liebig's letters, which would probably be of great historical importance, have been preserved.

Since the resignation of the Chair by Playfair in 1869 the flag of chemical progress in the University has been kept flying by the present occupant and by his versatile predecessor who, happily, is still with us. Emeritus Professor Crum Brown's name is well known to chemists everywhere in connection with graphic formulæ, with the relation of chemical constitution to physiological action, with the theory of benzene substitution, with some of the problems of stereo-isomerism, with the electrolytic synthesis of dibasic organic acids and with a great variety of other subjects, and in many of these he was a pioneer. Sir James Walker also has a long record of important researches, and at his own hands and those of his pupils and other co-workers active investigation goes on steadily. The institution of the new Chair of Chemistry as applied to Medicine (1919), with George Barger as first occupant, has provided a new centre for the prosecution of chemical research in the University; while the erection of the extensive new Chemical Institute now proceeding at West Mains Road will furnish ample accommodation and equipment for the exploration of new fields of inquiry.

Of graduates in Chemistry, the University has sent many to all parts of the Empire and elsewhere, and some of these have given good account of themselves in extending our knowledge in special branches. Of these and of others who served the University in various ways, the names of Sir James Dewar, Frederick Guthrie, Edmund A. Letts, Orme Masson, and Alexander Smith may be recalled. For Dewar's physical work, see page 25.

In connection with discoveries made in the University laboratories within comparatively recent times, the one most worthy of mention is that of the persulphates, by Hugh Marshall, late Professor of Chemistry in University College, Dundee. The formation of potassium persulphate was first observed by him in 1891, in the course of experiments designed to effect the production, in an electrolytic cell, of cobalt alums.

This imperfect sketch cannot be appropriately concluded without reference to two noteworthy nineteenth-century Edinburgh chemists whose work was mostly carried on outside the University. One of these is Dr David Boswell Reid, who acted for a time as assistant to Hope, but who conducted both theoretical and laboratory courses in chemistry, from 1833 till 1847, in premises which are now included in the Surgeons' Hall. Reid's laboratory is said to have been amongst the earliest, if not actually the earliest, in Britain which was publicly opened to students desiring practical training in chemistry. The other chemist is Dr George Wilson, the genial author of the *Life of Cavendish* and of a large number of papers upon chemical subjects, some of considerable importance. Wilson taught chemistry and had a laboratory in Brown Square (a square which no longer exists—its site is partly occupied by the Dental School). He was appointed in 1855 to a newly instituted Chair of Technology in the University. He died in 1859.

L. D.

INDUSTRIAL CHEMISTRY

While Edinburgh has for long been a centre of manufacture in various departments of Applied Chemistry, it is a matter of some difficulty to trace the connection of these local industries with Edinburgh as a centre of Medicine and Science, and to show how far these industries have added to the knowledge of Applied Science. These matters are buried in the past, and it is only here and there that we get indications of progress made by co-operation between the manufacturer and the man of science.

Among the industries which may be regarded as branches of Applied Chemistry, Edinburgh has for long been a great centre of Brewing, owing to the excellent water for brewing purposes to be obtained by sinking wells in the valley lying between the old University Buildings and the Calton Hill. In addition, the town contains important distilleries.

As a centre of the publishing trade, which has doubtless grown up owing to the presence of the University and of the Law Courts in the Capital of Scotland, there are important paper-mills in the neighbourhood of Edinburgh.

The city is also a centre of rubber manufacture, and the manufacture of chemical fertilisers is another important local industry. In addition, it is the largest centre in this country for the preparation of Petroleum from Paraffin Oil Shale, discussed in a separate article.

It is, however, in the special line of the manufacture of Drugs that Edinburgh is worthy of attention, a line of manufacture which has probably grown up on account of the old and important Medical School and the demands made locally for medical preparations. Doubtless there have been inter-communications and experimenting on the part of the members of the medical faculty on the one side and of the drug manufacturer on the other, but it is difficult to obtain any actual definite information on this subject, with one exception to which I shall shortly refer.

It is interesting to note that, in the year 1661, the Governors of Heriot's Hospital established in the garden surrounding the School a botanic garden, and instructions were given that herbs should be grown there that were valuable for medical purposes. This was followed by the "Medicine Garden" started by Sir R. Sibbald in the grounds of Holyrood, and the subsequent twin gardens at Trinity Hospital and the University garden at Kirk o' Fields. It is quite possible that Edinburgh's renown as a centre of drug manufacture is due to the presence of these gardens in the town. In this matter of drugs, the Edinburgh drug manufacturer has been specially famous for the production of alkaloids, such as morphine and strychnine; the first commercial manufacture of morphine in Great Britain was undertaken in Edinburgh in 1833. For a long time the town rejoiced in having a practical monopoly in the production of drugs of this kind, and the whole list of drugs which are now prepared by leading firms and which have a world-wide distribution is very considerable. Among antiseptics the manufacture of the double cyanide of zinc and mercury was first undertaken in this town at the recommendation of Lord Lister when he occupied the Chair of Surgery in the University, and it has been since a considerable local industry.

It is, however, only in one department of drug manufacture, namely, that of chloroform, that we get a clear vision of the close relationship between the Medical School—which was constantly progressive and engaged in scientific and medical research—and the Edinburgh manufacturer. The first suggestion for an anæsthetic which was to be inhaled came from Sir Humphry Davy, the discoverer of the properties of nitrous oxide gas. This was followed up by experiments in America on the use of ether as an anæsthetic. At this time (1840) James Young Simpson had been appointed to the Chair of Midwifery in the University of Edinburgh, and he was impressed by the importance of the discovery of a useful anæsthetic, and was constantly engaged, along with his assistants, George Keith and Matthews Duncan, in experiments in this direction. Among these possible drugs was chloroform, then known as "perchloride of formyle," first discovered by Soubeiran in 1831 and Liebig in 1832, the composition being first accurately ascertained by Dumas in 1835. Mr Waldie had suggested to Simpson the possibility of this drug as an anæsthetic and had promised to send a sample, but it did not arrive.

Consequently Messrs Duncan & Flockhart were asked if they could supply the drug, and Mr Hunter of that firm undertook its preparation and supplied the first sample to Simpson, apparently staying up all night to complete the distillation. At first Simpson was not favourably disposed towards the drug, as it struck him as not being sufficiently volatile, and the sample was laid aside. It was the custom of Simpson and his assistants to meet in the evenings, pour various suggested anæsthetics into tumblers, and inhale them in order to find out results. One evening they had been as usual trying various experiments, and then, remembering the sample of perchloride of formyle, they searched for it, found it under a heap of waste paper, charged their tumblers and began to inhale. The following account of what happened is from the *Life of Sir James Y. Simpson*, written by his daughter:

"A moment more, then all was quiet, and then a crash. On awakening, Dr Simpson's first perception was mental. 'This is far stronger and better than ether,' said he to himself. His second was to note that he was prostrate on the floor, and that among the friends about him there was both confusion and alarm. Of his assistants, Dr Duncan he saw snoring heavily, and Dr Keith kicking violently at the table above him. They made several more trials of it that eventful evening, and were so satisfied with the results that the festivities of the evening did not terminate till a late hour, 3 a.m."

The credit of one of the greatest discoveries in medicine is therefore shared by one of our well-known local manufacturing firms, who have for long been one of the principal manufacturers and distributers of chloroform, and made the first sample which was tried and proved successful.

In conclusion, it is of interest to note that the first manufacture of sulphuric acid in lead chambers was established by Dr Roebuck in Prestonpans in 1749, and that during the War a centre for the manufacture of

T.N.T. was established in Edinburgh as a result of researches undertaken in the University Chemical Laboratories under Sir James Walker.

A. P. L.

The Scottish Shale Oil Industry

This manufacture, at one time carried on over all the coal-fields, is now confined to a narrow band of country, 12 miles west of Edinburgh, which stretches from the Firth of Forth southwards towards the west end of the Pentland Hills. The suitable shales are found in the Calciferous Sandstone series lying geologically under the Carboniferous Limestone and over the Old Red Sandstone. The upper division of it, some 3000 feet thick, has about a dozen seams, 3 to 6 feet thick. A narrower strip lies east of Edinburgh and was worked at Pentland. The Coal Measures, which once lay above, have been ground off by glacier action and have left the shales within working reach of the surface. They are much contorted and have many faults, down-throws and up-throws of over 1000 feet, and have much intruded igneous rock, so that there must be much preliminary boring before a pit can with confidence be sunk.

There are five companies all united now under one Directorate. About 3,000,000 tons of shale are retorted per year, and 9000 men employed, 4000 being miners. Meanwhile several works are stopped owing to the Coal Strike (April to July).

A shale-oil works forms a complex organisation, covering perhaps 30 acres and putting through about 2000 tons of shale per day. In the crude works are benches of tall retorts, stacks of condenser-pipes, scrubbers, ammonia stills, etc., all on a large scale. In the refinery are stills, great washers for acid and alkali, freezing machines, filter presses, paraffin sweating chambers, filling and packing sheds, with shops for smiths, fitters, joiners, coopers, plumbers, etc. Two of the companies have candle-making and acid works.

The products are solid paraffins; oils (sp. gr. 0·7–0·9) for lubricating and gas-making, and for lamps and for fuel for internal combustion engines; and spirit. Also still coke, and, most important, sulphate of ammonia. A very rich gas is given off during the coking of the heavy oil stills, and is used for lighting the villages. It was also used for motor-buses during the War.

The oils are mixtures of the paraffin and olefine series of hydrocarbons, with some naphthenes and trace of benzenes. The crude oil contains also series with less hydrogen than olefines, and also phenols and compound ammonias of the pyridine series; and the quinoline series, besides unknown substances. The tars extracted by the chemicals have not been at all thoroughly investigated.

The originator of the industry was James Young, born in Glasgow, 1811. He was a working cabinet-maker, and in his youth attended the chemistry class of Professor Thomas Graham, where he had Lyon Playfair as fellow-student. Graham noticed his aptitude, and appointed him class-assistant. He accompanied Graham to London, and remained with him as assistant for in all seven years. Afterwards he became manager of Muspratt's chemical works for four and a half years. He substituted cast-iron vessels for silver in the manufacture of caustic soda, and made other improvements. He had an appointment in Tennant's chemical works, Liverpool, and while there Playfair wrote telling him of a petroleum spring in a Derbyshire coal pit (where the successful petroleum bore is now), and suggested he should erect works and refine it. This he did in 1848. The yield of oil was about 300 gallons a day, and the products were lamp and lubricating oils. He separated some solid paraffin and tried it for candles. Was not this the first petroleum works on modern lines?

The spring, however, soon showed signs of failing. Young thought it had originated from the action of heat on the coal, and set himself to produce petroleum artificially. He tried many English and Scottish coals with low-temperature distillation, and at last fixed on Boghead gas coal or Torbanehill mineral as suitable. There was a small basin of it near Bathgate. It occurred near the base of the Coal Measures overlying the Millstone grit. He took out his patent for the low-temperature distillation of *coal* in 1850, and had the first retorts working before the end of the year. Associated with him was Meldrum, his manager in Derbyshire, and E. W. Binning, who supplied capital. The manufacture prospered, and the result was that country people and the poor everywhere were supplied with a brilliant cheap light for the first time. We have difficulty in imagining the old times of darkness visible when farmers and even lairds had their parlours lit with only *one* candle. Other works were started. There were six in 1860, 90 in 1870, only 30 in 1873, 26 in 1880, 14 in 1890, 9 in 1900. Young had much litigation; was the Torbanehill mineral really a coal? Was distillation of shale an infringement of his patent? This caused much interesting scientific investigation. Boghead coal was exhausted in 1862. It yielded 100 to 120 gallons of crude oil per ton. Shales yielding 45 to 20 gallons were used, but they had the extra product, sulphate of ammonia.

Young had taken out his patent in America also, and works were started there and "coal-oil" became the light of the people. This stirred up the Americans to explore their own petroleum, and Drake struck oil in 1859. In the 'sixties petroleum was imported into Britain, and soon in large quantities. Later on there was competition from Russia and elsewhere, and prices got very low. The industry had many ups and downs, prosperity and growth alternated with defeat and casualties. New inventions brought temporary success. In the end more than a hundred works were stopped, with much loss of capital to the country.

Young started at first with a small horizontal iron retort, but soon adopted a vertical one. Each works had a genius of an engineer, and many forms of retort were tried, vertical and horizontal, some patented, with much variety of condenser. The fuel was coal, and the direct flame, if not carefully managed, spoiled the oil and soon burned through the retort. N. M. Henderson in 1873 patented a retort which utilised the spent shale as fuel and got the right temperature without care and produced an oil rich in lubricating oil and solid paraffin. Early retorts aimed at a large yield of lamp oil, now it was heavy products. Peruvian guano for the farmers gave way about 1880 and sulphate of ammonia sold for £22 a ton. Nitrate of soda was largely imported by 1890 and sulphate fell to £8, and oils were very cheap. The industry was saved by William Young and George Beilby, who patented their retort in 1881. It is the only type now in use. By it the ammonia was at once doubled; and enlarged and improved by Henderson, Bryson, Crichton, Thomson and others, the ammonia was trebled. A modern retort is a tall vertical column, of circular or oblong section, down which there is a continual passage of broken shale from a hopper on top. The upper part is of iron, and in this the shale is made to yield its crude oil; and the lower part is of firebrick highly heated, and into the bottom of the retort steam is passed in superheated by the outgoing spent shale and sweeping upwards gives its oxygen to the residual carbon to produce fuel gas, and its hydrogen to the nitrogen of the shale to form ammonia. Each works has its own form of retort.

As the weaker works stopped the stronger ones were enlarged, which made possible economies and new applications of skill and science; and on the whole there has been a gradual increase of the total shale put through per annum. The best shale came first, and now at much extra expense 20 gallon shales are used. Although poorer in oil they are richer in ammonia, and so the industry lives on.

Oilworks chemists were not generally permitted to publish the results of their experience, and with their death their knowledge was lost. Andrew Taylor in the early days described the operations, and later R. Tervet did the same. Tervet also had papers on retorting, ammonia production and paraffin refining. Many men trained in shale-oil works have distinguished themselves in other lines, for instance J. Gray of Sunlight and Sir George Beilby, F.R.S. Beilby wrote the history of shale retorting, and important papers on ammonia production.

The country, and indeed the world, owe much to James Young, whose insight and practicality originated the industry. He acquired a fortune and estates, and died in 1883. He was an original Fellow of the Chemical Society of London, an honorary LL.D. of St. Andrews and F.R.S. of London. He gave £10,500 to endow a Chair of Technical Chemistry in what is now the Royal Technical College, Glasgow.

D. R. S.

III

GEOLOGY

IN the beginning, man turned to the mineral kingdom for tools and weapons. Since then an ever-increasing perception of mineral worth has in large measure determined the direction and scope of human activity. Among other things, it has provided a powerful incentive to geological research.

The Edinburgh district remained practically destitute of metal resources until, in 1760, clayband ironstone, followed in 1801 by blackband, entered the category of Scottish ores. There is, in fact, only one early record of the working of a metalliferous deposit in this neighbourhood, and it concerns a copper lode formerly exposed in a tributary of the Water of Leith, close to Currie. Even this lode seems to have yielded a very meagre return; but it is interesting to recall the high anticipations which were once entertained regarding its educational possibilities. A letter of Privy Council, dated 1683, suggests that the property should be given by the King to a certain "skilful man" named Joachim Gonel, "since by the working of this one mine the true method thereof might be made known to the whole nation." It is no mere coincidence that this Joachim was a German. Historical records show abundantly that from an early date Scotland's international position in matters metalliferous has been largely that of a learner.

Coal figures much more prominently than the metals in the geological environment of Edinburgh. It has been suggested that the monks of Newbattle were the first workers of coal in Scotland ; and a charter granted to them somewhere between 1210 and 1219 is regarded as the earliest notice of coal-mining extant. The Newbattle monks continued to work their coal-field for some three and a half centuries, until they themselves came to an end during the tempestuous reign of Mary Queen of Scots.

The year 1563 saw the first of many Acts of Parliament restricting the export of coal. This in itself shows a species of geological forethought ; and it is well to remember, before venturing upon criticism, that the coal reserves at that time were much smaller than they are to-day. Improvements in drainage and transport have far more than counterbalanced the immense output of intervening centuries. Until 1600 there is no mention of mechanical drainage of Forth collieries. During the seventeenth century bucket-dredges were commonly employed ; and in the early part of the eighteenth century these were gradually replaced by pumps.

It is clear that so long-continued an intimacy with coal as has been indicated above must of necessity have led to a very considerable accumulation of geological lore. We are extremely fortunate in possessing a contemporary record in the form of a *Short History of Coal*, by George Sinclar, as part of a work entitled *The Hydrostaticks* (1672). Sinclar appears to have been a native of East Lothian. He occupied the Chair of Philosophy and Mathematics at Glasgow University for twenty years, though not continuously, since his opposition to episcopacy led to his ejection in 1666, and he did not return until the Revolution of 1688. During his retirement he was variously employed, in large measure as a mining engineer in the Lothians ; and it is to this circumstance we owe his *Short History of Coal, and of all the Common, and Proper Accidents thereof ; a Subject never Treated of Before.*

It will convince any one of the continuity of geological thought from the seventeenth century onwards to find

Sinclar using the words "cropp," "dipp," "rise," and "streek" with the same meaning, though not the same spelling, as holds good to-day. Moreover, he employs the terms "gae," "dyke," or "trouble," just as Scots miners still do, to cover both the dykes *and* the faults of modern text-books. He also speaks familiarly of the "Great Seam" of Midlothian. And, finally, when he refers to clays and shales, it is by their Scots name "tilles," which, with restricted application, has found its way into the glacial literature of the world.

Sinclar understood thoroughly the geometry of an ordinary faulted coal-basin. As regards "gaes," he cites the experience of the coal-hewers that the direction of inclination of the "vise" or "weyse" shows the side on which the coal will be found to be "down." As regards dip, he agrees with those who contend that dip, unless interrupted by a gae, continues to a centre, where the coal, or whatever it may be, "takes a contrary course" which brings it up once again to the "grass." This proposition he applies to the Midlothian basin, boldly accepting a hypothesis that carried him in imagination 3000 feet below the limit of his experience. What appealed to him was the fact that he could follow the outcrop of the Great Seam fairly satisfactorily round the landward margin of the basin.

Incidentally Sinclar explains that he knew the Great Seam of Midlothian in its various exposures by its character, by the rocks lying above, and by the neighbouring coals below. He also speaks of many other coals lying well above the Great Seam in the heart of the basin. A notable beginning had been made in the deciphering of Scottish Carboniferous stratigraphy.

Apart from the geometrical side of his subject, Sinclar seems to have made little headway with his study of the rocks. As a geologist he cannot compare, for instance, with his predecessor Leonardo da Vinci, or his contemporaries Nikolaus Steno and Robert Hooke. He makes no mention of fossils; and, when he says that coal near a "gae" of whin-rock is rendered "as if it were already burnt," he is merely summarising common experience—he is not propounding a geological theorem.

A century elapses, and the curtain rises upon the commencement of a struggle from which Geology was destined to emerge a recognised branch of Natural Science. From our point of view two great figures bulk so largely as almost to monopolise attention. Here stands James Hutton, citizen of Edinburgh. Sir Archibald Geikie acclaims him the Father of Modern Geology. During his lifetime his followers may have numbered half a dozen. And there stands Abraham Gottlob Werner, Inspector and Teacher in the Freiberg Academy of Mining. In many ways he ranks as the Mahomet of his Science. Students flocked to his standard, and eventually constituted a veritable army eager to establish their master's doctrines throughout the civilised world. Wherever they went they carried with them two leading articles of faith, the supernatural potency of water, and the almost unquestionable authority of their great teacher.

James Hutton (1726–97) was born and bred in Edinburgh. On leaving the University he was apprenticed in 1743 to a lawyer; but his employer, on finding his office fast degenerating into a chemical laboratory, acted "with much good sense and kindness" (as Playfair rather naïvely remarks) and set the young scapegrace at liberty.

The only occupation that seemed promising at this stage was medicine. Accordingly Hutton returned to the University, and afterwards proceeded to Paris and Leyden, where he completed his studies, and, in 1749, took his degree. This is as far as Hutton went in his medical career. He decided that agriculture was preferable, and to learn the ancient art he went, in 1752, to a Norfolk farm. From this centre he made many journeys on foot into different parts of England, and during his travels discovered how interesting a subject

Geology is. After an excursion to Holland, Belgium and Picardy, Hutton returned to Scotland in 1754, and settled on a farm in Berwickshire. He continued, however, to take a keen interest in Geology, and in 1764 he made a geological tour of the Highlands. In 1768 he let his farm and settled down in Edinburgh to enjoy, with less interruption, the society of his intellectual friends.

The first publication of his long deliberations we owe to the Royal Society of Edinburgh, established by royal charter in 1783. In the spring of 1785 the *Theory of the Earth* was read, and was published in 1788 in the first volume of the Society's *Transactions*. The republication of Hutton's *Theory* in book form was due to a virulent attack by Kirwan, afterwards President of the Royal Irish Academy. Two volumes of the *Theory* appeared in 1795. The manuscript of a portion of a final volume subsequently passed into the care of the London Geological Society, and was published by them, acting upon Sir Archibald Geikie's advice, in 1899. In what follows this highly interesting posthumous publication is not discussed.

The twelve years between the reading of the paper and the appearance of the book provided Hutton with the opportunity for six important geological excursions, on which he was accompanied by one or more of his personal friends. Hutton undoubtedly had a genius for friendship. Some friendships are lasting; Hutton's seem to have had an hereditary quality. Sir John Hall of Dunglass and Mr Clerk of Elden both handed on their places in Hutton's esteem to their respective sons.

It was not only in the field that Hutton benefited from his discussions with his friends. Black's discovery that a gas is liberated on heating limestone led Hutton to the view that the decomposition of limestone might be checked, even at a high temperature, by the application of pressure. Watt's improvements of the steam-engine are almost certainly responsible, one would think, for Hutton's view of the earth as a machine actuated by heat, and safeguarded by volcanoes. The Clerk family brought with them the wisdom of the coal-fields. Sir James Hall and Professor Playfair succeeded, after their master's death, in advertising to the world the rich heritage he had left behind of geological observation and deduction; and thus, in large measure, laid the foundations upon which Lyell in 1830 reared his *Principles*.

The earth, according to Hutton, is a machine of peculiar construction adapted to the use of plants and animals. From beginning to end this machine must follow the same laws of action as control it to-day—otherwise one must admit some flaw in its design. A philosopher is thus able to trace the working of the earth, firstly, by studying such operations as are carried on before his eyes in accessible regions; and, secondly, by critical examination of the products of that other great group of activities which are not themselves open to his investigation.

Animal life is dependent on plant life, plant life upon soil, and soil originates through disintegration of solid rock. Once solid rock disintegrates, its debris falls a prey to streams and rivers and is carried slowly but surely to the sea. The various processes of erosion are observable realities; and, considered in reference to the actual details of landscape, they are found to be related as cause is to effect. Two impressive thoughts follow immediately: the one is the immensity of time required to develop a landscape when progress is so slow that Roman roads are still traceable across British hills; the other is the inevitable end to which erosion seems to be tending, namely, the obliteration of all dry land.

In conformity with Hutton's hypothesis of design, there is abundant evidence of reconstruction, acting somewhere out of sight, to counterbalance the slow progress of erosion. The solid rocks in the great majority of cases are found, on close examination, to be nothing else than consolidated shingle, sand, mud, or shell-banks, standing high and dry above the waters of the sea in which they obviously accumulated. These fundamental facts had been settled by previous generations of observers. Two questions presented themselves to Hutton: What has led to the consolidation of these marine deposits? How is it that they are no longer covered by the sea?

In consolidation, Hutton thought that he could recognise the operation of heat acting in association with pressure. This inference, though well supported by close reasoning and acute observation, is now admittedly wrong in many of its applications. Hutton regarded heat-consolidation as of fundamental importance to his *Theory*; but in his further deductions he was continually referring direct to Nature for inspiration—and time, which has sadly sapped the foundations, has left much of the superstructure of his system intact.

Having recognised deep-seated heat as attested by consolidation, Hutton next proceeded to suggest that heat in all probability supplies the motive power of his machine. It is fair to paraphrase this conclusion, and say that Hutton's *Theory* is that the earth is a heat-engine.

Hutton claimed that the ancient consolidated sediments, now exposed to view, have been elevated by the expansive power of heat. Most other geologists had withdrawn the sea, instead of elevating the sediments. Hutton, however, emphasised the folded and fractured nature of the upheaved sediments. Incidentally, one may mention, he regarded the Crag of Norfolk and the raised beaches and strand-lines of the Forth and Cromarty as indications of a comparatively recent uplift—but in this case, of course, he had less evidence to build upon.

The last main feature of the *Theory* that need be noticed is the rôle assigned to volcanoes. These latter are the safety valves of the engine. Where they open on land, they prevent a profitless upheaval of continents to barren altitudes characterised by perpetual snow.

Where they open under sea, they are quenched by contact with cold water, so that loss of heat is reduced to a minimum. In Hutton's philosophy, submarine eruptions are impossible. Volcanoes that persist in activity in regions covered by the sea give rise to "subterraneous lavas" injected among the submarine strata. This hypothesis he bases upon the difference of amygdaloidal basalt and vesicular lava. Certain Vulcanists, notably Dolomieu, had accounted for this difference by infiltration. Hutton could not admit percolation of water through what he considered impervious basalt. Amygdales for him were original igneous crystallisations, and the frequent occurrence of calcite among their contents indicated consolidation under considerable pressure. Thus Hutton deduced—quite wrongly—that basalts are all of them deep-seated intrusions.

It may be suggested that Hutton might have derived his heat-engine theory from a comparison of the widespread whinstone of his native land with the products of active volcanoes, instead of adopting a much more circuitous and hazardous line of argument based upon the consolidation of sediments. But, says Hutton, "when first I conceived my theory, naturalists were far from suspecting that basaltic rocks were of volcanic origin; I could not then have employed an argument from these rocks as I may do now." This remark of Hutton's suggests a comparison of his dates with those of Desmarest. Hutton developed his *Theory* somewhere about 1760, read his paper in 1783, and published in 1785. Desmarest realised the volcanic origin of columnar basalt in the Auvergne (and, by analogy, in the far-away cliffs of the Giant's Causeway) in 1763, read his paper in 1765, and published in 1774. Arduino in his 1759 account of the Vicentin seems to have forestalled Desmarest in the identification of trap as lava. But no one need doubt Hutton's statement that he had to determine the igneous origin of whinstone on the strength of local evidence alone.

One of Hutton's outstanding achievements was his discovery of the igneous origin of granite. The crystalline structure of this rock suggested to him consolidation from a molten condition ; but without examination of the field evidence he could not decide whether the once molten granite had acted (like basalt) as an igneous intrusion, or whether it had remained quiescent. His delight can readily be pictured when, in 1785, he saw granite veins cutting mica-schist in Glen Tilt. His guides could scarcely believe that the elderly gentleman from Edinburgh, standing so excitedly before them, had found nothing more valuable than little bands of quartz and felspar.

Another of Hutton's masterpieces is his discussion of the relations of the Primaries and Secondaries (in the old sense of the words) as revealed to him in 1787 on the banks of the river Jed. He had long searched for a good exposure of this important contact, for he thought that if he could show repetitions of upheaval and depression, it " would add great lustre " to the *Theory*. His account of the section is full of detail, and his deductions in regard to the sequence of events run as follows : (1) elevation and flexure of marine sediments ; (2) planation of the same by " rivers, winds, or tides " ; (3) subsidence, giving opportunity to fresh deposit ; (4) renewed elevation. Hutton also showed that igneous rocks occur in the district, some of them earlier than (2), others later than (3).

It is curious in the face of all this that both Lyell and Macculloch have found fault with Hutton for not according subsidence a place in the economy of the globe. It must be admitted, however, that Hutton used subsidence far too little ; he certainly should not have conducted sands and gravels to oceanic depths by means of current action.

Hutton's conception of the connection of landscape with commonplace erosion is strikingly modern in its more essential features. It is true that in this great matter he was anticipated by Desmarest—so far as publication is concerned ; but there can be no question of the originality of his views, and of the influence they had upon the development of science. "From the top of the decaying pyramids to the sea," he says, in summarising his argument, "throughout the whole of this long course, we may see some part of the mountain moving some part of the way. What more can we wish ? Nothing but time."

It can well be appreciated that Hutton was very loath to countenance any suggestion of widespread deluges. "Surely, general deluges form no part of the theory of the earth ; for, the purpose of this earth is evidently to maintain vegetable and animal life, and not to destroy them." It is a curious accident that this conservative outlook led Hutton to be the first scientist to suggest a former great extension of glaciers in the Alps. His task was to account for de Saussure's record of the distribution of Mont Blanc granite boulders, and yet not to call in the assistance of a deluge. "Let us now consider the height of the Alps, in general, to have been much greater than it is at present ; and this is a supposition of which we have no reason to suspect the fallacy ; for, the wasted summits of those mountains attest its truth. There would then have been immense valleys of ice sliding down in all directions towards the lower country, and carrying large blocks of granite to a great distance, where they would be variously deposited, and many of them remain an object of admiration to after ages, conjecturing from whence or how they came. Such are the great blocks of granite which now repose upon the hills of *Salève*" (vol. ii, p. 218). From the termination of the glaciers to the passes of the Jura, Hutton proposed to conduct the boulders, ice-rafted, down river courses which existed before the present-day hollow of Geneva was eroded.

In 1815 Playfair stood among the great boulders on the slopes of the Jura. He saw one monster, 2520 tons in weight, which had performed a journey of fully 70 miles and still remained rough and angular. Francis

Jeffry, who published in 1822 a biographical account of Playfair, gives the substance of his dead friend's pencil notes concerning this giant erratic: "A current of water, however powerful, could never have carried it up an acclivity, but would have deposited it in the first valley it came to, and would in a much less distance have rounded its angles, and given to it the shape so characteristic of stones subjected to the action of water. A glacier, which fills up valleys in its course, and which conveys the rocks on its surface free from attrition, is the only agent we now see capable of transporting them to such a distance, without destroying that sharpness of the angles so distinctive of these masses. That mountains formerly existed of magnitude sufficient to give origin to such extensive glaciers, is countenanced by other phenomena observed in the Alps, and does not imply any alteration in the surface so great as the supposition of a continued declivity between the two extreme points, which is, after all, insufficient to remove the objection arising from the sharp angles of these rocks." Charpentier, when eventually he and Venetz realised this truth for themselves and proceeded to declare it to an unbelieving world, generously acknowledged Playfair's priority. But it seems to have escaped notice from that day to this that Playfair was only applying a lesson he had learnt from his great master. It is a grand thought indeed that Playfair standing on the Jura could in imagination see Alpine glaciers pressing forward through the passes at his feet. But what are we to think of Hutton? He sat in his library in Edinburgh with nothing to guide him but the mistaken writings of de Luc and de Saussure; and sitting there, he pictured Alpine glaciers extended far out into the Swiss plain until they abutted against the hills of Salève—a smaller conception; yes, but in its circumstances and its originality unquestionably more amazing.

Hutton's principle of uniformity did him great service in many directions, but it helped to render him oblivious to biological progress in time. A few thinkers, more especially the younger men, such as Werner (1749–1817), Giraud-Soulavie (1752–1813) and William Smith (1769–1839), were in advance of Hutton in this respect ; but it is well to remember that William Smith's *Table of the Order of Strata, with their embedded Organic Remains, in the Vicinity of Bath,* was not dictated till 1799, two years after Hutton's death, and was not widely circulated until 1801.

Hutton in his researches saw "no vestige of a beginning—no prospect of an end." This remark applies to the working of the great earth-machine designed, as he thought, to maintain an unchanging population of plants and animals—"all subservient to the use of man." The question naturally arises what was his view regarding the antiquity of man. Here Hutton adopts a Sphinx-like attitude which will probably be differently interpreted by different readers. "The Mosaic history places this beginning of man at no great distance ; and there has not been found, in natural history, any document by which a high antiquity might be attributed to the human race."

John Playfair (1748–1819), even before he became Professor of Mathematics, spent much of his time in Edinburgh, mixing in the distinguished circle of which Hutton was one of the leading lights.

Hutton's death in 1797 led Playfair to draw up an abstract of his friend's work, with a view to preparing a biographical memoir. He found Hutton's writings very nearly unreadable, and he decided to present the *Theory* in a more attractive form. No labour was spared, and in 1802 the *Illustrations of the Huttonian Theory of the Earth* appeared, followed in 1803 by the *Biographical Account.* The *Illustrations* will always rank as a masterpiece of lucidity. One important difference between Hutton's and Playfair's statements of their case may be gathered from a comparison of the two following quotations. What is the final cause of the universal waste we see about us ? asks Hutton —"Is it in order to destroy the system of this living world, that the operations of nature are thus disposed upon the surface of this earth ? Or, Is it to perpetuate the progress of that system which, in other respects, appears to be contrived with so much wisdom ? Here are questions which a Theory of the Earth must solve ; and here, indeed, must be found the most material part by far of any Theory of the Earth." "To trace the series of these revolutions," Playfair quietly answers, "to examine their causes, and thus to connect together all the indications of change that are found in the mineral kingdom, is the proper object of a Theory of the Earth."

There is a great deal of additional matter in the *Illustrations*, combined with a wide reference to the views of contemporary writers. We find Playfair able to meet, but not to silence, one of the most important criticisms advanced by the Neptunian School. Shells, it was claimed, could be hammered out of an Irish basalt exposed at Portrush. Specimens came to Edinburgh, and, with Lord Seymour and Sir James Hall, Playfair examined them and found that the shells were included in baked shale. Another of the particularly interesting features of the book is a discussion of the many evidences of recent alterations in level collected by various observers along the coasts of Europe. And yet another is a critical examination of the claim advanced by Cuvier and fellow-naturalists that a notable change could be detected in the life of past ages. Playfair enumerates five genera or species of extinct mammals as definitely demonstrated, and he also admits substantial changes in shells, corals, and plants as a characteristic of the geological past. He then passes quite naturally to another aspect of the matter : if the animals of bygone ages differed in form from those of to-day, they probably also differed in habit. Pallas had carried the elephants and rhinoceroses of Siberia from the plains of India on the waters of a marine inundation. Cuvier saw that such a transport was incredible. Still he retained the marine inundation, limited its duration to a moment of time, and coupled it with an instantaneous change of climate such as would allow of a perennial preservation of frozen corpses. Playfair, however, deduced from the evidence the reasonable suggestion that these extinct monsters not only subsisted in Siberia, but also, that they had lived under much the same climatic conditions as have continued ever since.

Playfair travelled extensively in Britain during the Napoleonic wars, and in 1815, on the Declaration of Peace, he set out for a memorable journey through France, Switzerland and Italy. He had in view a second edition of the *Illustrations*, but all that remains are the pencil notes from which his biographer Jeffry was able in 1822 to rescue the glacial suggestion, already quoted, and several other items of interest. We find in these notes of Playfair's a record of vesicular tops and bottoms of lavas as a diagnostic feature to which attention had not hitherto been drawn; and, in another place, a mention of lava, on alluvium, "closely resembling a greenstone even in the fracture, and containing calcareous matter."

One feels that if the second edition of the *Illustrations* had been produced it would have added materially to the position of the Edinburgh School. As it was, when Playfair returned home to resume his academic duties after an absence of seventeen months and a journey of 4000 miles, it was not long before failing health interrupted his work, and in 1819 terminated his versatile career.

Side by side with Playfair, Sir James Hall (1761–1832) stood for many years one of the two great buttresses of the Huttonian doctrine. His allegiance had been won by Hutton's conversation, not his writings; and his devotion to his master was ever mingled with a considerable independence of outlook. In his early unbelieving days Hall travelled in Switzerland and Italy, and in the latter country he had, during part of his stay, the great advantage of Dolomieu's company.

As regards the lessons he learnt in Switzerland, he always felt that Hutton's interpretation of scenery and of the transport of boulders was incomplete. Instead of extending the glacial conception, as Playfair afterwards did when similarly situated, he introduced a deluge theory, stript of the more wonderful of the attributes with which it had been clothed by de Saussure and de Luc. He suggested an earthquake-wave, and floated the erratics on fragments of disrupted glaciers. Returning to Scotland he set to work to find similar evidences. In a paper read before the Royal Society of Edinburgh, 1812, he described crag-and-tail, moulding, striation and boulder clay in the neighbourhood of the city; and he successfully connected these phenomena through a self-consistent, though in large measure incorrect, interpretation which involved an oceanic wave sweeping across the site of Edinburgh from west to east.

His Italian studies led him to realise the close similarity of lava and whinstone. He also saw the dykes of Somma, and in after years felt certain that he had been looking at material that had welled up from below. But of all his observations in this connection, the most interesting was his recognition of a dyke where "the substance in immediate contact with the mountain is vitreous, the rest being common lava. This is fully explained by our experiments" (he announced long afterwards in 1798 to the Edinburgh Royal Society) "if we suppose the stream to have flowed in a cold crevice." Here is the first recorded instance of the chilled edge of an intrusion being turned to good effect by a geological observer.

Hall's experiments have just been mentioned, and they constitute his chief claim to celebrity. He is admittedly the founder of experimental geology. His interest in this connection was roused by an accident in a glass factory in Leith where the melt consolidated with stony crystallisation. He found on experimenting that he could ensure a glassy or stony consolidation by regulating the rate of cooling. He communicated this result in abstract in 1790 to the Edinburgh Royal Society. He tried hard to arouse Hutton's interest in the matter, since some of Hutton's opponents declared that basalt differed from lava in that it graduated into greenstone, which itself has a distinctly crystalline structure; but he failed. Hutton was old; he was afraid of small-scale experiments; and he did not want to countenance them even though there seemed promise that their results might lend apparent support to his teaching. Hall therefore dropped the subject until Hutton died in 1797. The results of his subsequent researches are given below. The year quoted in each case is that on which an account was read before the Edinburgh Royal Society.

1798. Lavas and whinstones give identical glasses on melting and rapid cooling, and identical "crystallites" on remelting and slow cooling.

1805. Limestone can be fused and crystallised to marble under high pressure.

1812. The convolutions of the strata of the Berwickshire coast suggest compression by a horizontal thrust—these last two words are in the original. The effect can be imitated experimentally. The sideways push is probably connected in Nature with the introduction of granite.

1825. Sand can be consolidated to sandstone by raising to a red-heat under brine.

It is now fully time to give an account of the rival School. Its local leader, Robert Jameson (1774–1854), was born in Leith. *Robinson Crusoe* and *Cook's Voyages* had much to do in deciding the course of his life; and during his school days he was a notorious truant, pursuing insects and other living creatures instead of the wisdom of the classroom. He turned to surgery for a livelihood, and, in 1792, started to take a Natural History course under Professor Walker at the University. Between 1794 and 1799 he travelled extensively in the Scottish Isles, and was thus able to publish his well-known mineralogical description of them in 1800, the same year as he set out for Freiberg to perfect his knowledge in the Wernerian School.

Jameson returned to Edinburgh in 1804, and was appointed the same year to the vacant Chair of Natural History, which he occupied for fifty years.

Jameson's position in Geology may be regarded as that of local representative of the brilliant Freiberg teacher. Werner was a preacher, not a writer, and it happens that Jameson's account of the Wernerian doctrine is reckoned the equal of any that has been produced. A short summary of Werner's life-work is attempted below—based for the most part on Jameson's *Mineralogy* (1804–8).

A. G. Werner (1749–1817) came of a family with three hundred years' connection with Saxon mining. He saw the whole world through mineral spectacles. Population, civilisation, architecture, sculpture, agriculture, commerce and war are all regulated by mineral distribution; and Werner delighted to proclaim the fact with an eloquence which proved irresistible.

Werner made a determinate language his first objective. He understood that no progress was possible until people could express themselves in words. He addressed himself to mineral classification, carrying forward the work begun by his countryman Bauer (Agricola), and by the Swedes Linnæus and Cronstedt. It is perhaps significant that Linnæus and Werner both aroused exceptional enthusiasm among their pupils. The one was more especially engaged upon the classification of the animal and vegetable kingdoms, the other upon that of the mineral kingdom. Onlookers felt that order was developing out of chaos. One realises on glancing through Werner's classification that it would often enable a student to name a specimen—so that an essential step had been taken towards the goal of scientific intercourse.

On passing from minerals to rocks, Werner still regarded precise classification as a prime necessity.

His scheme of nature, as set out by Jameson, reads as follows:

(1) In Primitive times a universal ocean; no detritus; all deposits chemical and very irregularly accumulated.

(2) In Transition times a decrease of ocean; crests of primitive mountains appear; detritus mingles with chemical deposit; enough of chemical deposit to consolidate the gathering sediment with steep dip on submerged slopes; life begins.

(3) In Floetz times a further decrease of ocean; flanking ridges of transitional rocks exposed; detrital and organic deposits begin to predominate over chemical; thus more or less horizontal stratification is alone possible (floetz means flat); organic life advances in type.

(4) Ocean falls to approximately present-day limits; present-day conditions prevail with little chemical deposit except calc-sinter and bog-iron-ore.

In 1788 Werner was compelled to add to his original scheme a Newest Floetz-Trap Formation, requiring the assumption of a general deluge, the waters of which disappeared as mysteriously as they originally came into being. Such a universal scheme, pushed with all the ardour of Werner's enthusiastic disciples, is of little importance in the present sketch, except in so far as it explains Jameson's antagonism to the Huttonian Theory.

As an example, consider Werner's view that granite was the oldest of his Primitive precipitates. Hutton, as we have already seen, interpreted granite as an igneous intrusion often of later date than adjacent sedimentary rocks. Here was a difference that could be tested by field-observation. But when Hutton and his followers pointed to granite veins, Jameson replied that there is a newer granite, and search will demonstrate that these veins cut the older granite, which alone is the old original of Werner; or again, he argued, that these veins are not true granite veins,

JAMES HUTTON.

but contemporaneous veins belonging to the mica-schists with which they are associated. As time went on, Jameson developed the idea of contemporaneous veining well beyond the limits of comprehension.

The subdivision of that part of the Floetz Class which antedates the Newest Floetz-Trap Formation has much of interest. Werner adopted the local stratigraphical succession of Saxony and attributed to it a world-wide extent. To begin with came the basal Permian Sandstone which Werner variously styled *Aelter rother Sandstein* or *Rothe tode Liegende.* It could be recognised by its characters combined with its juxtaposition, on one side, with greywacké. It is not surprising that when Jameson, in 1808, introduced the name Old Red Sandstone into British literature, he stated that the formation occurs abundantly in England, and probably also in Scotland. One must remember that the Carboniferous rocks of the Hartz are largely greywackés, and that, in Jameson's early days, the relation of the Coal Formation to the Rothliegende had still to be determined. The name Old Red Sandstone suited British stratigraphical needs so excellently that it soon took firm root, and naturally gave rise, in the land of its adoption, to the correlative title of New Red Sandstone. In fact, it would be difficult after these long years to be certain of the alien origin of the best known of all British formational names were it not explained to us by William Phillips in his *Geology of England and Wales*, 1818.

Jameson during his fifty years of office had many distinguished pupils, among them Ami Boué, Necker de Saussure, J. D. Forbes, Edward Forbes, Hibbert, James Nicol, Charles Maclaren, Fitton, Harkness, Lord Greenock (Cathcart), and Sir William Logan. For the most part his students seem to have been greatly indebted to their Professor, though many of them embraced igneous interpretations well in advance of their master's views. This latter fact is illustrated, for instance, in a classification of geologists under four headings, published in 1825 by Ami Boué in Jameson's *Edinburgh Philosophical Journal.*

(1) All geologists accept extinct volcanoes; (2) most accept Tertiary basalt as volcanic; (3) many accept the trap of the Secondaries; (4) some (including Boué) regard granite, syenite and porphyries as igneous.

Charles Darwin in his autobiography refers to Jameson in the following terms: "During my second year [1826] at Edinburgh I attended Jameson's lectures on geology and zoology, but they were incredibly dull. The whole effect they produced on me was the determination never to read a book on geology or in any way to study the science. . . . Equally striking is the fact that I, though now [1876] only sixty-seven years of age, heard the Professor in a field lecture at Salisbury Craigs, discoursing on a trap dyke with amygdaloidal margins and the strata indurated on each side with volcanic rocks all around us, say that it was a fissure filled with sediment from above, adding with a sneer that there were men who maintained that it had been injected from beneath in a molten condition. When I think of this I do not wonder that I determined never to attend to geology."

These were the days when the Wernerian-Huttonian conflict was drawing to a close. How bitter party feeling had been in the matter can now scarcely be credited—unless, as Lyell points out, allowance is made for the political circumstances of the time. The French Revolution was an ever-present source of terror. Hutton's mechanical interpretation of the earth, and the glimpse that it gave into an immeasurable depth of time, seemed calculated to loosen the restraints of authority—and this was a danger that could not be tolerated.

Jameson outlived the time of strife. In addition to his mineralogical and stratigraphical explorations, and his kindly guidance, ever at the disposal of students, his main services to contemporary science were his prominent share in the inauguration of what is now the

Royal Scottish Museum, his founding and presidency of the Wernerian Natural History Society (1808–*c.* 1848), and his Editorship of the *Edinburgh Philosophical* and *New Philosophical Journals* (1819–54).

It is now necessary to retrace our steps, and to consider briefly work done by one of Hutton's contemporaries, who, though a Neptunist, did not subscribe to the Wernerian doctrine. John Williams, Manager of Gilmerton Coal-works, began life as a Welsh miner, but presently found his way to the Midlothian Coal-field. He is chiefly remembered for his *Natural History of the Mineral Kingdom* (1789), which gives an exceptionally full account of the Coal Formation.

In many ways Williams, in his treatment of his main subject, reproduces the same excellent features as have been noticed in Sinclar's book; but he is sufficiently advanced to realise that the Coal Formation has been deposited, and that it contains the remains of plants and animals. He also argues on sound field evidence that it is of later date than the rocks of the principal mountains, such as the Pentlands. His Neptunian philosophy was of the Noah's Flood variety, and he accumulated all the rocks of the earth's surface within a period of a few weeks; the stratified rocks were sorted by tides; the unstratified sank in quiet water. Needless to say, he did not think very highly of Hutton's *Theory of the Earth*.

Williams, as an expert on the Coal Formation, was worthily succeeded during the earlier part of the nineteenth century by a well-known mining engineer, Robert Bald, who published several important papers, including one in the Wernerian *Memoirs* of 1821. Further work on the same lines resulted in a more ambitious account by Dr David Milne (Milne Home) entitled *The Coal-Fields of the Lothians* (1837). Here a thoroughly good treatment of the subject is illustrated by horizontal and vertical sections, accompanied by a map showing outcrops, faults, dykes and dips. Milne's description of Lothian stratigraphy down to the marine limestones underlying the lower workable coals has merely been improved upon in detail by later workers ; but his suggested correlations with England have been greatly modified.

Let us now consider the work of William Nicol (1768–1851), a popular lecturer in Edinburgh on scientific subjects, and also an enthusiastic investigator. In 1828 he invented the Nicol's Prism, an absolute essential in modern petrographical technique ; and in 1831, in Witham's *Observations on Fossil Vegetables*, he published an account of how he prepared the many thin slices of fossil wood of which a microscopical description is furnished in the text. Nicol has explained (*Edin. New Phil. Jour.*, xvi, 1834) that the preparation of thin slices of fossil wood was nothing new, for Sanderson, an Edinburgh lapidary, had already obtained transparent sections by a difficult and uncertain process. What was new about Nicol's slicing was the method, and this led immediately to important advances in palæontology, and eventually to the opening up of a new world of discovery for petrology. On his death, Nicol bequeathed his instruments and preparations to his friend Alexander Bryson, who prepared numerous additional thin slices of rocks and minerals, more especially to observe the well-known fluid cavities described by Brewster in 1823. These slides greatly impressed Sorby when he saw them on a visit to Edinburgh, and, through his agency, petrologists, after about twenty years of lost opportunity, began to realise the possibilities of the situation.

The Rev. John Fleming (1785–1857) was for many years one of Scotland's leading naturalists and geologists—and a wonderfully persistent Wernerian. His connection with Edinburgh dates from his attending classes at the University in 1802 ; in 1845 he returned to the city to occupy the Chair of Natural Science in the New College—the Free Church Theological Hall.

Fleming, in the summer of 1827, discovered fish remains in the Old Red Sandstone of Fife. He immediately recorded the find in the *Fife Herald* and later the same year in *Cheek's Edinburgh Journal.* This appears to be the first published record of Old Red Sandstone fishes; but Agassiz certainly overstates the case when he writes: "C'est sans contredit au célèbre Professeur d'Aberdeen (M. le Doct. Fleming) qu'est due la première decouverte de poissons fossiles dans le terrein devonien." Murchison in 1827 told the Geological Society of London how fishes had been obtained for many years past from the Caithness Flags quarried at Banniskirk.

Fleming's researches in the Old Red Sandstone carried him a long way, as may be judged from the following quotation from Sir Andrew Ramsay's 1880 Presidential Address to the British Association. "In the year 1830 the Rev. Dr Fleming of Edinburgh read a paper before the Wernerian Society, in which he boldly stated that the Old Red Sandstone is a fresh-water formation of older date than the Carboniferous Limestone."

What Fleming had done for the Old Red Sandstone was in large measure repeated by Dr Samuel Hibbert (1782–1848) for the Burdiehouse Limestone lying within the Carboniferous Formation. In 1833 Hibbert found in this limestone abundant remains of entomostraca, fish and land-plants, unaccompanied by any trace of ordinary marine organisms. He therefore concluded that the limestone was of fresh-water origin. He communicated his results in a series of papers to the Edinburgh Royal Society (1833–34), and also to the British Association when it met in Edinburgh in 1834. His discoveries were of first-class importance; and they attracted additional attention, since Hibbert at first imagined that some of his specimens were the teeth of a reptile. Agassiz, who attended the Edinburgh meeting of the British Association in quest of fossil fish, was soon able to correct Hibbert's mistake; and to make amends, asked leave to call the original piscine owner of these interesting teeth *Megalichthys Hibberti.*

Unfortunately, however, owing to misapprehension, he conferred this name on a Coal-Measure fish of another genus; and thus it comes about that the Burdiehouse giant has now to be content with the title *Rhizodus Hibberti*.

In 1837 Dr Robert Paterson in an account of the flora and fauna of the Wardie shales criticised Hibbert's lacustrine interpretation of the Burdiehouse Limestone, and suggested that it should be termed an estuarine rather than a fresh-water deposit. The two ideas grade insensibly into one another, but it is noticeable that Traquair, with his ample knowledge of fossil associations, preferred to employ the term estuarine in relation to Burdiehouse fishes.

Hugh Miller (1802–56) is distinctively the stonemason geologist of Cromarty, but his connection with Edinburgh was long and fruitful. In 1830 he first found fossil fishes on the western side of the Southern Sutor of Cromarty, but he had no scientific guidance on the subject until, in 1836, he read Hibbert's memoir on the Burdiehouse Limestone. Not long after this he got into touch, through correspondence, with Murchison and Agassiz. He was always a writer, and his share in church controversy led to an invitation to Edinburgh to take up the editorship of the *Witness*, a newspaper projected by the Non-Intrusion party of the Church of Scotland. Thus he came to Edinburgh in 1840, there to remain until his tragic death in 1856. Within a few months he began his *Witness* articles on geology and natural history which, in book form, have brought him undying fame. The first series of articles dealt with the Old Red Sandstone, and appeared in time to supply one of the main sensations of the memorable 1840 Glasgow meeting of the British Association. His *Testimony of the Rocks* (1857), in final proof for separate issue, engaged his attention on the last day of his life. Of his collected works, twelve volumes remain, and in addition to this there are hundreds of other articles which were familiar in their day to readers of the *Witness*. It is generally admitted that Hugh Miller's writings did more to popularise geology in the English-speaking world than those of any other man.

Hugh Miller was not the first Edinburgh editor to teach geology in the columns of his newspaper. Charles Maclaren (1782–1866), with the co-operation of William Ritchie, launched the *Scotsman* in 1817 as a liberal newspaper, and for nearly thirty years acted as an editor. In 1828 he began to contribute geological sketches to his newspaper, which at that time appeared twice weekly. His more important researches are summarised up to date in his *Geology of Fife and the Lothians* (1839). This work, on its stratigraphical side, is noteworthy for the introduction of the term Calciferous Sandstone (in a wider sense than is used to-day), and for the demonstration of unconformities in the Pentland Hills separating Upper from Lower Old Red Sandstone, and Lower Old Red Sandstone from Silurian—though these are not the exact formational names which he employed. In igneous geology Maclaren's chief contribution was his study of Arthur's Seat. He distinguished lavas and sills, and emphasised the transgressive relationship of the later volcanic products of the hill as compared with the earlier. The later products are largely agglomerate, which Maclaren originally pictured as forming an unconformable cap resting upon the older lavas already tilted and eroded. Maclaren eventually abandoned this view, but not before it had been accepted by Sir Archibald Geikie in the *Geological Survey Memoir*, 1857. In 1875 Judd, adopting Maclaren's later view, accounted for the discordance by assigning the central agglomerates and intrusions to a vent from which the adjacent lavas had been erupted; and Peach in the 1910 edition of the *Survey Memoir* has established Judd's interpretation with a wealth of local detail that renders his account the most valuable description of an ancient dissected volcano that has yet appeared. It is wonderful how many of Maclaren's observations and deductions remain unaffected, and it is unquestionable that the long discussion of the discordance which he so early appreciated has had a notable influence on geological thought.

A year after the publication of Maclaren's book, the British Association met in Glasgow. Buckland by this time had satisfied himself of the glacial origin of many of his British *Reliquiæ Diluvianæ*, and had persuaded Agassiz to come over and check his conclusions. A discussion took place at the British Association meeting, and afterwards Buckland and Agassiz set out for Glen Roy. It is interesting to recall that Agassiz' explanation of the wonderful strand-lines of that region first appeared in the *Scotsman*; but what appeals most to Edinburgh geologists in this connection is Agassiz' exclamation—"That is the work of the ice"—which fell from his lips when he saw the overhanging glaciated face at the southern foot of Blackford Hill, whither in January 1841 he was conducted by Charles Maclaren.

Another publicist of Edinburgh who wrote on geological matters was Robert Chambers (1802–71). In 1844 he produced anonymously the *Vestiges of the Natural History of Creation*, in which the conclusion was reached that the principle of progressive development in the organic world must be admitted. The book was popular, and ran through eleven editions, but the secret of its origin was carefully guarded until its author had been dead for a dozen years. Chambers, like Maclaren, played a large part in winning acceptance for the glacial conception, and with this end in view travelled in Switzerland, Norway, the Faroe Isles and Iceland. Another keen investigator of glacial phenomena was Professor James D. Forbes (1808–68), whose great discoveries in physics are described on page 19. He studied the movement of glaciers in the Alps, and their striæ, and transported blocks among the Cuillin Hills of Skye. Edward Forbes (1815–54), the naturalist, who succeeded his old master, Jameson, in the Chair of Natural History, had in 1846 interpreted the isolated remnants of Scandinavian flora, characteristic of our mountain tops, as a heritage of the glacial epoch. For his brilliant work in biology, see the articles Zoology and Oceanography.

In 1854, the year of Edward Forbes's death, his friend Ramsay broke ground for the Geological Survey in Scotland. This soon led to Edinburgh becoming the centre of a local branch of the Survey, with H. H. Howell and A. Geikie as the initial personnel. Howell came to Scotland well versed in English Carboniferous stratigraphy, and was thus enabled in the 1861 edition of the *Edinburgh Memoir* to point out the local equivalents of the Millstone Grit and Coal Measures of his native land—a very important advance, supplemented in later years by W. Gunn's suggestions in regard to the subdivisions of the Lower Carboniferous.

Archibald Geikie, born at Edinburgh in 1835, and educated at the Royal High School and University, was drawn to Geology by the writings of Hugh Miller, to whom also he was indebted for an introduction to Murchison which paved the way to his entering the Geological Survey in 1855. He became in 1867 the first Director of the Scottish Branch of the Geological Survey, and in 1871 the first occupant of the Murchison Chair of Geology and Mineralogy in the University of Edinburgh. In 1882 he succeeded Ramsay as Director-General of the Survey, and removed to London. Ten years later he was knighted, and in 1914 received the Order of Merit.

Ramsay's influence is to be seen in Geikie's masterly paper to the Geological Society of Glasgow, 1863, in which he advocated the claims of land-ice ; and equally clearly in his delightful *Scenery of Scotland* (1865), where every feature of the country is attributed to erosion guided by rock structure. Murchison's influence is even more apparent, for it led Geikie into two geological pitfalls, the one in the Southern Uplands, the other in the North-West Highlands. In the former locality the correct solution was supplied by Charles Lapworth

(1842–1921), then teacher at Galashiels, afterwards (1881) Professor of Geology at Birmingham, who showed that what Murchison and Geikie had regarded as mere fossiliferous intercalations were in reality infolds with a sequence that could be determined by careful attention to their graptolitic contents. In the latter locality the two Survey Geologists were withstood by Professor James Nicol of Aberdeen—an old pupil of Jameson's—who argued that the line of junction of the Eastern Gneiss with the Durness Sediments was a line of fault. When eventually Callaway, Lapworth, Peach, and Horne showed that Nicol's dislocation is a reality, too little credit perhaps was given to Murchison and Geikie for their recognition of the extensive superposition of Eastern Gneiss on unmetamorphic sediments. Nicol seems to have had a difficulty in thinking in three dimensions, for he gave it as his opinion that "a comparatively very small amount of inversion and extension of older crystalline masses will suffice to explain any of the Scottish sections."

It is universally acknowledged that Sir Archibald Geikie has done more than any other living man to further the progress of igneous geology. His early work for the Survey led him to Arthur's Seat and the Pentland Hills, where he learnt much from Maclaren's able descriptions. Before long he became officially acquainted with most of the igneous masses of the valley of the Forth, and in his holidays visited the Hebrides. And so throughout the years his knowledge increased, until he was able to gather together his many publications, and develop from them and other sources a complete up-to-date account of the *Ancient Volcanoes of Great Britain* (1897). The book is simply invaluable to all interested in such matters.

It is difficult to single out for comment any particular feature of Sir Archibald Geikie's work on his favourite subject, but certainly among the most notable of his contributions to science are his many descriptions of agglomerate-filled vents in Ayrshire, the Lothians and Fife. These descriptions began to appear in 1866, and were concluded in the *Geology of Eastern Fife* (1902).

Sir Archibald Geikie's Geological Maps, his text-book, and his important biographical and historical memoirs place his fellow-workers under further obligation. It is scarcely necessary to state that the preparation of the present sketch has been greatly facilitated by reference to Sir Archibald Geikie's writings, along with those of Ralph Richardson, John Horne, and Karl von Zittel (translated by Mrs Ogilvie Gordon).

James Geikie (1839–1915), also educated at the Royal High School and the University of Edinburgh, joined the Geological Survey in 1861. His interests turned more and more to glacial matters, while those of his brother became increasingly centred on igneous problems. In 1874 he published the *Great Ice Age*, of which subsequent editions appeared in 1877 and 1894. In 1881 he produced his *Prehistoric Europe*. These two great books furnish an epitome of much of his life-work. He succeeded to the Murchison Chair in 1882, and occupied it until 1914.

James Geikie's main themes in glaciology are the former great extent of land-ice, the efficacy of ice-erosion, and the importance of interglacial periods. A very helpful feature of his writings is the wealth of information they impart concerning results obtained by continental observers. It is an open question at the present time what will be the final verdict regarding the scope and application of interglacial theories, but it is generally agreed that James Geikie occupied a premier place in his science, and focused attention upon a number of most interesting and elusive problems. It is pleasant to recall that Penck and Brückner in 1909 dedicated *Die Alpen im Eiszeitalter* to the Edinburgh Professor.

James Geikie was greatly indebted to James Croll (1821–90), a fine example of a self-educated Scotsman. Croll was born in Perthshire and trained as a wheelwright, but subsequently moved to Glasgow. From 1864 onwards he published a series of articles on the cause of glacial epochs. These attracted general attention, and in 1867 Croll was appointed to a post in the Edinburgh Office of the Geological Survey. In 1875 he produced his famous *Climate and Time,* wherein his earlier papers are combined and extended. He maintained that glacial cycles have arisen indirectly through cosmical causes of such a nature as to lead to a rhythmical succession of cold and warm periods. Astronomers are divided in their judgement of Croll's hypothesis regarding the origin of the Ice Age, and geologists have not yet succeeded in establishing a demonstrable relationship between fact and theory in this direction. In other less recondite problems, however, Croll's suggestions have been abundantly vindicated. For instance, in 1870 he interpreted the available evidence regarding the glaciation of Caithness and the northern islands as indicative of a union of Scottish and Scandinavian ice on the floor of the North Sea. This bold conception was later established by the detailed researches of Peach and Horne published in 1879–81.

James Bennie (1821–1901) was another geologist deeply interested in interglacial research. He was born in Glasgow, and he remained for many years in the West as a weaver, and, later, in a stationer's warehouse. He presently developed a wonderful skill in obtaining fossils from the Carboniferous and Glacial deposits of the Clyde area. In fact, he had already established his reputation, when he was asked in 1868 to follow his friend Croll to Edinburgh, and to join the Scottish Staff of the Geological Survey as Fossil Collector. With increased opportunities, he continually added to his discoveries. The outstanding feature of his technique was the washing of sediments for microzoa which furnished specialists with hitherto unprocurable material. As typical of his results among Scottish Carboniferous rocks, one may note his discovery of holothurian remains, his additions to our acquaintance with macrospores, and his demonstration in many of the soils of the period of abundant fragments of the skin of scorpions and eurypterids (*Proc. Roy. Phys. Soc. Ed.*, 1886). During his investigation of old lake alluvia at Corstorphine, Hailes and elsewhere, he was rewarded by finding arctic plants previously unknown in the Scottish Lowlands. A list of these plants was furnished by Clement Reid at the Edinburgh Meeting of the British Association, 1892. In this connection reference should be made to the important researches of F. J. Lewis on the alternations of vegetation in the Scottish Peat Mosses (*Trans. R.S.E.*, xli, xlv, xlvi, 1905–7), which he attributed to oscillations of climatic conditions.

The glacial researches of Peach and Horne in the Shetlands, Orkneys and Caithness, to which reference has already been made, were carried out during holiday excursions. Peach had joined the Geological Survey of Scotland in 1862, Horne in 1867. Their official work at first took them into the Lowlands and Southern Uplands. Accordingly they had to consider at close quarters the new interpretation of the latter region as it took form in the hands of Lapworth. They became converts, and when an opportunity was afforded, with Arthur Macconochie's help as Fossil Collector, they carried out a rapid revision of the whole area—which had been mapped by many officers of the Survey. Two of the principal discoveries of the revision were palæontological. Peach observed minute organisms in certain Arenig-Llandeilo cherts, and these were shown to be radiolaria by Professor Nicholson and Dr Hinde; Macconochie and Tait found fish remains in Downtonian shales, and these placed in Traquair's hands "opened out to us a new vista in the field of palæozoic ichthyology."

The Southern Upland revision by Peach and Horne was not commenced until the secret of the North-West Highlands had been definitely won. Four geologists were more particularly concerned in the final interpretation of this classic region of overthrust movement.

Dr Callaway, as a result of field studies continued from 1880 to 1882, published in 1883 an explanation of the apparent anomalies of the district on the basis of overfolding and thrusting, in which he realised that the "overthrow" is locally "more than a mile in width." Lapworth by detailed mapping in 1882 and 1883 arrived at similar conclusions, which he published in 1883 and 1885. Peach and Horne took up the work in 1883, and were able to convince Sir Archibald Geikie of the truth of the overthrust theory, and to present an account of it in the columns of *Nature* (vol. xxxi, p. 31, 1884). Their fuller report in the *Quarterly Journal* of the London Geological Society appeared in 1888. It is this paper, and the subsequent maps and Memoir of the Geological Survey, which, in Suess's words, render our northern mountains transparent. It must be remembered that Callaway's work was less minute in character than that of his successors, and that Lapworth's health broke down under the stress and excitement of those heroic days of discovery. Lapworth, on the one side, and Peach and Horne, on the other, have clearly stated that they worked independently, and that the close agreement of their results is not to be ascribed to collaboration.

The appearance of the 1888 report made a profound impression upon the scientific world. From that day to this, the North-West Highlands have been a place of pilgrimage for geologists of all nationalities; the clean-cut overthrusts, mylonisation, *schuppen structur* and the rest can be examined in solid diagrams prepared by Nature and rendered available by detailed mapping. One individual thrust-mass has been shown to have suffered horizontal displacement to an extent of more than ten miles; how much more no man can say. In 1892 Marcel Bertrand, de Margerie and von Richthofen were taken over the ground by Peach. Bertrand has given a valuable account of his impressions. It is quite clear that this great leader of Alpine interpretation saw much during the excursion which he had not hitherto realised in his own native mountains.

It is particularly fitting that Peach should have had so large a share in interpreting the North-West Highlands, since it was his father, C. W. Peach, whose discoveries of fossils in the Durness Limestone, from 1854 onwards, first brought the district geologically into prominence. The most interesting advance in this direction of recent years in the North-West Highlands is Macconochie's find of Olenellus in 1891 in some likely shales noted by Horne. Peach has supplied descriptions of this and later finds of trilobites. In fact, some of Peach's principal contributions to geology have been on the palæontological side—mainly in connection with crustacea and arachnids—and a large proportion of his material has been due to Macconochie's skill in collecting.

Peach has also done much to advance the study of volcanoes. His work in connection with Arthur's Seat has already been noticed. His recognition of fallen masses of chalk and other Mesozoic rocks in the throat of a Tertiary volcano in Arran affords one of the romances of Scottish Geology. His realisation of a zone of true lavas in the Highland Schists has thrown a flood of light on many vexed problems.

But if Peach has had a wider field of research, Horne has wielded a readier pen, and the geological world realises to the full its indebtedness to both investigators.

One cannot turn away from the interpreters of the North-West Highlands without a passing reference to H. M. Cadell's experimental repetition, on a laboratory scale, of some of the phenomena of thrusting. And Cadell's name immediately brings to mind his important physiographical suggestions regarding the significance of certain through-valleys of the West Highlands which, he claims, are relics of a supplanted drainage system.

Another Edinburgh geologist who is remembered in connection with the North-West Highlands is M. F. Heddle (1828–98), Professor of Chemistry in St. Andrews.

But his life-work was not so much Geology as the indefatigable exploration of Scottish Mineralogy, and in this he achieved outstanding success. Many of Heddle's results were published posthumously by J. G. Goodchild, for several years (1889–1906) the custodian of the Geological and Mineralogical Collections exhibited in what is now the Royal Scottish Museum.

Edinburgh science and the Royal Scottish Museum are closely associated through the labours of Dr R. H. Traquair (1840–1912). Traquair was born in Perthshire, but received his schooling and University education in Edinburgh. He was a naturalist from boyhood, and his first meeting with a fossil fish was on the seashore at Wardie. After taking his medical degree, he taught for a few years at Cirencester and Dublin, but he returned to Edinburgh in 1873 as Keeper of the Natural History Collections in the Museum, a post which he held with rare distinction until his retirement in 1906. His study was in the main palæozoic fishes. His opportunities were great in this respect. The Hugh Miller and other collections were ready to his hand, and he had funds to add additional specimens. Moreover, the Geological Survey and private collectors were only too anxious to submit their material to his judgement.

Agassiz had already developed a very superficial classification of fossil fishes, based largely upon the external characters of scales. Traquair went deeper and founded his conclusions on the fundamental characters of the skeleton. It is not surprising that Traquair's detailed study of the osteology of the Carboniferous Palæoniscidæ (1877) and Platysomidæ (1879) led him to reject Agassiz' classification, and to replace it by another based upon anatomical structure. The opportunity afforded by the Survey discoveries of fish in the Downtonian rocks has already been referred to. Traquair applied his customary method and again reached conclusions of extreme zoological interest.

Fortunately for geologists, Traquair was deeply interested in fossil associations as indicative of conditions of deposit, and also in the possibility of using fossil fish as guides in stratigraphical classification. His *Distribution of Fossil Fish Remains in the Carboniferous of the Edinburgh District* (*Trans. R.S.E.*, xl, 1903) gives an excellent account of his conclusions. Marine and estuarine fishes are distinguished, and the latter are divided into an older and a younger fauna. The exact stratigraphical line separating the two estuarine fish faunas of the Central Valley of Scotland is difficult to fix, but it lies somewhere in the Millstone Grit. The younger estuarine fauna is geographically persistent, for it continues southwards into the Coal Measures of England. The older estuarine fauna seems much more limited, and there is a remarkable divergence in the Lower Carboniferous estuarine fishes found on the two sides of the Southern Uplands. Traquair clearly recognised the distinctions between Lower and Upper estuarine fish as early as 1884 (*Geol. Mag.*).

In 1887 Traquair began a detailed study of the fishes of the Old Red Sandstone. He agreed with Murchison and Salter in recognising three main divisions—Lower, Middle, and Upper ; and within these major divisions he was able to establish a number of important zones.

In 1911 he published a memoir on Wealden fishes for the Musée Royal d'Histoire Naturelle de Belgique.

While Traquair was busy with fossil fishes, another investigator, who may be claimed for Edinburgh, was equally engaged with fossil plants. Dr R. Kidston, though born in Renfrewshire, and never a citizen of Edinburgh, has for many years been closely associated with the Edinburgh Royal and Royal Physical Societies, and has been a regular visitor at the Edinburgh Office of the Geological Survey, where he has named the ever-increasing collection of fossil plants. His work has been entirely palæobotanical, and in great measure deals with the external characters of plant remains embedded in Carboniferous and Old Red Sandstone rocks. It would be difficult to trace the first recognition of the zonal value of plants in Carboniferous stratigraphy. Certainly, by the time Kidston undertook his self-imposed task, a good beginning had already been made on the Continent by Geinitz, Weiss, Zeiller, Grand'Eury, Renault, Stur and others. But much remained to be done, particularly in our country, and it may be claimed, as a feature of Kidston's life-work which appeals especially to geologists, that he has been insistent throughout upon the accurate geological localisation of material with which he has dealt. Before his time, fossil plants were often recorded with only a vague mention of locality and generally none at all of horizon. Needless to say, the subject was in a bewildering state of confusion, from which Kidston's work has gone far to rescue it in our own and other lands. Advantage has been taken of his unique knowledge by the authorities of the British Museum (Natural History), and also by those of the Musée Royal d'Histoire Naturelle de Belgique, for whom in the one case he drew up a catalogue and in the other a memoir.

The main results published by Kidston during his long investigation into the zonal distribution of Carboniferous plants (see *Trans. R.S.E.* from 1881 to 1893) are (1) a sharp division between Lower and Upper Carboniferous, corresponding precisely with Traquair's break in the succession of estuarine fishes, and (2) other valuable, though less definite, groupings within the scope of these two great divisions. In regard to the life-zones of the Old Red Sandstone, Kidston has stated his opinion as to the definite floral distinction of the Lower, Middle, and Upper divisions. On the more purely botanical side, his work on the Pteridosperms, and his combined researches with Professor Gwynne-Vaughan on the Osmundaceæ (*Trans. R.S.E.*, xlv, xlvi, 1905–6), and with Professor Lang on the Old Red Sandstone plants of Rhynie, have thrown a new light upon some of the most interesting problems of plant-classification and evolution. These last results have been and are being published by the Royal Society of Edinburgh (*Trans.*, lii, 1921).

The chert of Rhynie, which encloses the *Rhynia* petrifactions, is now so famous that it is a pleasure to recall Edinburgh's share in its discovery. The Rhynie chert was first found as loose blocks by Dr W. Mackie, an indefatigable non-resident member of the Edinburgh Geological Society. The paper in which he announced his discovery was read before the Society in 1913, and has served as the starting-ground from which all subsequent researches have been undertaken. Of course one of the first essentials was to get at the rock *in situ*, so as to determine its geological relations ; and this was accomplished by digging trenches in a field in which numerous loose blocks occurred at the surface.

This historical account has reached in places to our own day, but there is no intention to aim at bringing it uniformly up-to-date. Edinburgh is a busy centre of geological research. Investigations of oil-shales and discoveries of bauxitic clays have added new interest to the economic side of the science. A description of the Trap Dykes of Orkney has marked a renaissance of petrological interest in Scotland. Carboniferous corals have been sliced until they confessed their phylogeny. The obdurate sediments of the Highland Border have yielded tell-tale radiolaria, brachiopods and even crustacea. Cauldron-subsidences, ring-dykes and cone-sheets have been recognised at more than one volcanic centre. Theories of mountain structure have been advanced which recall the modern interpretations of the Alps. Contact-altered sandstones and shales, with their original clastic grains, their ripple-marks and their sun-cracks, have been described from near a granite margin where all around is paragneiss (*Geol. Mag.*, 1910 ; *Memoir*, 1912). In several of these advances a prominent share was taken by Dr C. T. Clough (1852–1916).

E. B. B. and D. T.

IV

ENGINEERING

EDINBURGH cannot claim to be a great engineering city, although certain important industries directly dependent upon engineering science, such as the manufacture of printing and paper-making machinery, brewing, and shipbuilding, are carried on within the city and in its immediate vicinity.

The Lothians and Fife are important coal-mining areas, and the shale deposits of West Lothian have been worked for many years and this has resulted in the establishment of a number of oil-refining works.

There will undoubtedly be big industrial developments in Edinburgh, in the Lothians and in Fifeshire in the immediate future; iron and steel works will probably be established, and shipbuilding will become a much more important industry at suitable centres both on the north and the south sides of the Forth.

It can, however, be claimed with truth that Edinburgh has had a fairly close connection with three of the most important of those engineering developments which have made possible the industrial revolution of the past century. Edinburgh men, or men who came to the city for their educational training, played a big part in the early stages of the solving of the problems of steam navigation, in the development of that network of railways which cross our country, and in the invention of the steam-hammer.

Our modern industrial life is, to a large extent, built up on the foundations laid by these early pioneers.

Cheap and rapid transport by sea and land are essential for that dense concentration of population in great manufacturing centres which modern factory methods demand.

The steamship and railways could never have reached their present development unless the metallurgical and other processes connected with the manufacture of iron and steel had been improved in such a way as both to increase enormously the output and to cheapen the cost of production; and the steam-hammer has played no mean part in the newer processes brought about by these improvements.

The problem of cheap and speedy sea transport was one which had to be definitely solved before it was possible for this country to embark upon the era of industrial development which has, in the century which has elapsed since the close of the Napoleonic Wars, entirely changed the current of national life.

For our textile industries the greater part of the raw material has to be brought from overseas, our blast-furnaces require immense supplies of iron ore from Spain and other countries, and in fact there is hardly one important manufacture which does not depend to a considerable extent upon overseas supplies, and these supplies must be transported cheaply and arrive in a steady stream.

The rapid growth of population brought about by this increase in manufacturing industries has made it impossible for us to grow within these islands the food required by our ever-increasing population, and therefore, just as we are compelled to import immense quantities of raw material for our manufactures, so are we forced to bring into our ports equally large supplies of all kinds of foods.

The security of our Empire, as we so quickly realised in the Great War, rests upon sea power, and sea power in turn rests upon continuous improvements in ship design and in methods of ship propulsion. It is therefore interesting to recall the early history of the attempts made by many inventors to apply steam power to the propulsion of sea-going craft.

Two of the most noted of these early workers at steam propulsion for ships were Patrick Millar and William Symington.

Although William Symington was not an Edinburgh man, having been born at Leadhills in 1763, he was educated at the Universities of Edinburgh and Glasgow, being intended for the ministry. His instincts, however, led him to abandon the ministry and to adopt the profession of a civil engineer. He, like Nasmyth, started on his mechanical career by designing a working model of a steam road carriage, and in 1787 took out a patent for the steam-engine he proposed to utilise for propelling his carriage. In this engine he obtained rotary motion by a system of chains and ratchet-wheels. While engaged on the design of this road carriage he was brought into contact with Patrick Millar of Dalswinton, Dumfriesshire, who had been for some years engaged on the problem of propelling vessels by means of paddle-wheels operated by manual power. James Taylor, who was then tutor in the family of Patrick Millar, and who knew Symington's work on the steam-engine, suggested to Millar that he should abandon the use of manual power for his paddle-wheels and utilise steam power; and eventually Symington was employed to design a set of small steam-engines, which were made in Edinburgh by a brassfounder named Wall. This engine was designed on the lines of Symington's steam-engine for his steam road carriage; the cylinders were 4 inches in diameter, and there was unfortunately the very complicated system of chains and ratchet-wheels for securing rotary motion. A boat fitted with this engine was tried on Dalswinton Loch in October 1788, and the trial was so far successful that Millar decided to carry out more complete experiments on the Forth and Clyde Canal. Symington was again employed to design a new set of engines, in this case with 18-inch cylinders, the engines being built by the famous Carron Company. The trials on the Canal came off in November and December 1789, a speed of 7 miles per hour being attained during the trials.

Patrick Millar was convinced as a result of these trials that no real success could ever be reached until a more satisfactory type of engine could be obtained, and he entered into correspondence with James Watt. Watt, however, rather threw cold water on the scheme, alleging that Symington had as a matter of fact been infringing Watt's patent rights, and finally Millar abandoned the whole scheme. In 1801, however, Lord Dundas, then a governor of the Forth and Clyde Canal Company, decided to make another attempt to utilise steam power for the propulsion of vessels plying on the canal, and he employed Symington to work out the necessary plans. Symington himself had realised by this time that his original type of engine was wholly unsuitable for driving paddles, and he accordingly designed a new type of engine. In this engine, patents for which were taken out in 1801, he employed, instead of the chains and ratchet-wheels, a piston guided in a straight path by rollers, the piston-rod end being connected by a connecting-rod to a crank attached to the paddle-wheels shaft. This engine was fitted to the tug-boat the "Charlotte Dundas," and the trials took place in 1802. During the trial the boat travelled from Lock 20 to Port Dundas, a distance of 19½ miles, against a strong head-wind, in 6 hours, towing two barges. The success obtained in the trials of the "Charlotte Dundas" entitles Symington to the credit of having designed the first set of engines for the steam propulsion of vessels on a practical scale, and it is interesting to remark that Robert Fulton, who launched the "Clermont," the first steamship built in America, on the Hudson River in 1807 was actually present at the trials of the "Charlotte Dundas."

Edinburgh University can claim her share in the development of our railway system owing to the fact that Robert Stephenson, the most noted of the early railway engineers, was one of her *alumni*. George Stephenson, the father, had no opportunity in his younger days of obtaining anything but a very scanty elementary education, and realising fully the defects of this want of a sound education, he determined that his son Robert, who was born in 1803, should have the best education he was able to give him. By the time Robert Stephenson was old enough to begin his educational training his father's financial circumstances had greatly improved; the boy was therefore sent to a good academy in Newcastle, and on the conclusion of his school courses was apprenticed to Nicholas Wood, M.Inst.C.E., in 1819. In the year 1821 his father was busy with the preliminary survey work of the famous Stockton and Darlington Railway, and he employed his son as one of his assistants. George Stephenson, however, made up his mind that his son should have a college training, and after careful inquiries decided that the most suitable place to send him to would be Edinburgh University, where he entered as a student in 1822. Robert Stephenson may be said to be the founder of the modern railway system of Great Britain. In 1833 he planned and laid out the London and Birmingham Railway, which was completed in 1838, and was the first railway into London. Many difficulties had to be overcome in the course of this work, and in solving the problems which he met with there is no doubt that Robert Stephenson had an advantage over other engineers of that time due to the courses in mathematics and science he had followed at Edinburgh University. One of his fellow-students at Edinburgh Unversity was George Parker Bidder, who was fortunate enough to be able to spend a longer period of time at the University, working specially at mathematics. In 1822 he was awarded the prize then given by the Magistrates of the City of Edinburgh for the study of higher mathematics. Bidder was a man of most extraordinary powers of mental calculation, and his exceptional gifts were described in a paper which he read in 1856 before the Institution of Civil Engineers. He thoroughly realised the benefits he had derived from his University training, and in 1846, as a testimony of his gratitude to his *alma mater*, he founded the Jardine Bursary, stating that he intended it to be a memorial of the munificence of Sir Henry Jardine, through whose generosity he was able to become a student in the University of Edinburgh. Candidates for this bursary must be natives of Scotland, and in the words of the founder they "must be of good character and of promising talent and ability."

The friendship Bidder formed with Robert Stephenson while they were fellow-students led to their co-operating later on in engineering work, beginning with the London and Birmingham Railway; and this partnership in engineering work endured for many years.

James Nasmyth, the inventor of the steam-hammer, was born at York Place, Edinburgh, on 19th August 1808, and was educated at the High School and later on at the University, where he attended courses of lectures given by Professor Leslie. His remarkable gift for mechanical design is attested by the fact that when he was only nineteen he was commissioned by the Scottish Society of Arts to design and build a steam carriage. This he successfully accomplished, and the carriage was tried during the years 1827 and 1828 on roads in the neighbourhood of Edinburgh.

In order to improve his mechanical training, Nasmyth in 1829 joined the staff of Henry Maudsley at Lambeth. A little later he returned to Edinburgh, but finally left Edinburgh in 1834 in order to start on his own account as a mechanical engineer in Manchester. The invention with which his name will always be associated was due to certain difficulties in connection with the engines of the famous "Great Britain" steamship, then under construction at Bristol in 1839. The original intention was to propel the "Great Britain" by paddles, but there were no means available at the time to forge the big paddle-shaft which was required. In his autobiography

Nasmyth states that as soon as he had applied his mind to the problem of designing a means for carrying out this piece of heavy forging, in little more than half an hour he had the whole contrivance in all its executant details before him in his scheme book. The builders of the "Great Britain" decided, however, to replace the paddles by a screw propeller, and there being no inducement to go to the expense of building the steam-hammer designed by Nasmyth, the matter remained in abeyance. The sketches which Nasmyth had prepared were, however, seen in 1840 by M. Schneider, the proprietor of the Creuzot Works, and a steam-hammer, on the lines contemplated by Nasmyth, was built at Creuzot and set to work in 1841. As soon as Nasmyth became aware of this fact he took out a patent in 1842, and the first steam-hammer in Great Britain was erected at Patricroft in the early part of the year 1843. In the earlier hammers the valves were always operated by hand. In 1843 Nasmyth invented a self-acting gear, but large hammers are still worked by hand according to Nasmyth's original plans.

This is not the place to refer to the controversy which has arisen as to whom the real credit for the invention of the steam-hammer should be given, but Nasmyth's claims are supported by most authorities.

It is perhaps interesting to note here that Nasmyth's father, Alexander Nasmyth, the well-known portrait and landscape painter, during the latter years of his life devoted considerable attention to architecture, and was responsible for many valuable suggestions as regards the laying-out of the New Town of Edinburgh, receiving a grant of money from the City Corporation for his services.

Another Edinburgh engineer famous for his mechanical skill was the late A. B. Brown of Rosebank Iron Works, who, by his numerous inventions in connection with starting engines and steering gears, did so much towards the improvement of the machinery employed in propelling and steering big sea-going steamers.

The Professorship of Engineering was not instituted at Edinburgh till 1868, although there had been a Professorship of Technology from 1855 to 1859, the occupant of the Chair being George Wilson. The first Professor of Engineering was Fleeming Jenkin. Although not a Scotsman, he was educated first at Jedburgh, and from there proceeded to the Edinburgh Academy, where Clerk-Maxwell was his senior and Tait his classmate. Later on the family removed to Paris, thence to Genoa, and from that city migrated to Manchester, where Jenkin became an apprentice in Fairbairn's Engineering Works. From Manchester he passed to Switzerland, where he was engaged in railway work. Shortly afterwards he became a draughtsman in the employment of Mr. Penn, the well-known marine engine builder of Greenwich. About this period he made the acquaintance of Lord Kelvin (then Sir William Thomson), and collaborated with him in many electrical problems, especially in connection with the laying down and repairing of deep-sea cables.

In 1868 he was appointed to the newly established Chair of Engineering at the University of Edinburgh, after holding for a short time the Chair of Engineering at University College, London, and he held the Edinburgh Chair until his death in 1885.

During the last few years of his life the invention to which he gave the name of "telpherage" occupied his whole energies and time. He described his scheme in a paper which he read before the Royal Society of Arts in the year 1884.

Jenkin explained at the outset of his paper that what he meant by the term "telpherage" was all modes of transport effected automatically with the aid of electricity. He was chiefly concerned with the conveyance of minerals and other goods at a slow pace and a cheap rate; he stated that a single suspended rope or rod was the most suitable carrier, and this would, if made of ¾-inch rods with supports at say 60 to 70 feet apart, carry five vehicles each loaded with 2 cwt. without excessive strain. Experimental lines were tried on the estate of Mr Pryor of Weston, on which a train of 1 ton was run successfully at a speed of 5 miles per hour.

At the conclusion of his paper he stated that he had worked out approximately the comparative costs as follows: Railways 1d. per ton mile, cartage 1s. per ton mile, telpherage line 2d. per ton mile; in the case of the road cartage no allowance had been made for the original cost and maintenance of the roads.

Unfortunately Fleeming Jenkin's untimely death prevented him from carrying to a successful conclusion his work on telpherage, and it was not until after his death that any real practical application was made of his ingenious invention.

When Oxford University established an Engineering Department the first occupant of the newly established Chair was Charles Frewen Jenkin, a son of Fleeming Jenkin. Edinburgh University can therefore perhaps justly claim that the Oxford University Engineering School is one of the fruits of the system of engineering education evolved by Jenkin when he came to Edinburgh in 1868.

The present Principal of the University of Edinburgh, Sir James Alfred Ewing, K.C.B., F.R.S., was a pupil and assistant of Fleeming Jenkin, taking his B.Sc. degree in 1878. No Professor of Engineering has had a more distinguished career than Sir Alfred Ewing, both as a teacher and original investigator. He built up the great School of Engineering at Cambridge from the very humble condition in which he found it till it became the foremost engineering school in Great Britain; and in spite of his teaching and administrative duties he found time to carry out original investigations of great importance and to write standard text-books in several branches of engineering science.

From Cambridge he passed to the Admiralty, where he entirely revolutionised the then existing system of training the officers of His Majesty's Navy, the beneficial effects of the reforms he carried out being fully proved during the Great War.

In spite of his onerous duties as Principal of a large University he has recently published a treatise on *Thermodynamics for Engineers* (1920). The volume has taken its place as the most important contribution to this branch of engineering science which has been published in this country. See also page 26.

Edinburgh is the headquarters of the Northern Lights Commissioners, the public body responsible for the lighting of the coast of Scotland, and the responsible office of engineer to this Board has been held now for a long period by successive members of a remarkable family of Edinburgh engineers. Robert Stevenson, born in Glasgow in 1772, was the son of a West India merchant. After his father's death his mother married Thomas Smith, Engineer to the Lights Commissioners, and young Stevenson entered his step-father's office as an apprentice. He eventually succeeded him as Engineer to the Commissioners, holding the office for nearly fifty years, and the office has remained in the Stevenson family right up to the present date. His greatest and most thrilling achievement was the design and building of the famous Bell Rock Lighthouse, begun in 1807 and completed five years later. He also designed the fine eastern road approach to Edinburgh round the slopes of the Calton Hill. Three of his sons distinguished themselves as Engineers, and two of them held the post of Engineer to the Commissioners. Alan, the eldest, born in 1807, became Engineer to the Board in 1843, and designed the Skerryvore Lighthouse, a wonderful piece of engineering work. David, the third son, who succeeded his brother as Engineer to the Board in 1853, was responsible for much important engineering work in connection with harbours, rivers and other branches of civil engineering. The youngest son of Robert Stevenson was Thomas, born in 1818. He too joined the firm and continued his father's labours by carrying out a series of valuable investigations on lighthouse illumination, the beneficial results of which are seen all round our coasts to this day. He took a keen interest in meteorology and was one of the originators of the Scottish Meteorological Society. He was the father of Robert Louis Stevenson, the famous novelist, essayist and poet. All the members of this gifted family combined with unique engineering gifts no mean literary skill, as attested by their valuable books and pamphlets and their many contributions to the proceedings of the various societies of which they were fellows or members. In Robert Louis Stevenson the engineering gift had disappeared, only to lead to greater splendour on the literary side.

It is interesting to remember that the present holder of the office of Engineer to the Lights Commissioners is a Stevenson.

Mr. James Leslie, who was the engineer to the Edinburgh Water Works, began in 1853 a service of valuable experiments on the loss by evaporation from the surface of reservoirs, on lines similar to those employed in the famous Nash Mills and River Lea experiments.

The great Forth Bridge is probably the magnet which draws so many engineers from all parts of the world to Edinburgh. It is true that Edinburgh men can claim no very important share in the design and erection of this great structure ; yet some account of the various schemes which have been proposed for overcoming the obstacle presented by the Firth of Forth to direct north and south travel on the eastern side of Scotland, and of the final solution of the problem, is desirable in any narrative of the connection of Edinburgh with engineering science. The first serious proposal was made in 1806, when a prospectus was issued inviting the public to subscribe to a fund for constructing a double tunnel under the bed of the Forth at a point west of Queensferry, but nothing came of the proposal. Then in 1818 James Anderson, an Edinburgh civil engineer, prepared a design for a chain bridge to be erected at about the site of the present bridge, but the designer's imagination was certainly much beyond his skill as a bridge designer, and this scheme also proved abortive.

It was not till 1860 that the matter was again taken up, and Sir Thomas (then Mr) Bouch prepared for the North British Railway Company designs for a railway bridge crossing the Forth about 6 miles west of Queensferry, the bridge to consist of a large number of central spans, each 600 feet long, with a series of smaller spans at each end. Authority for the construction of this bridge was actually obtained in 1865, but eventually the scheme was abandoned.

In 1873 a Forth Bridge Company was formed to carry out another design by Sir Thomas Bouch, namely, a suspension bridge with two spans of 1000 feet each. An Act was obtained in 1873, and the contract for its erection was let to Messrs W. Arrol & Company, the builders of the existing bridge. Preliminary operations were begun, but the terrible Tay Bridge disaster in 1879, which destroyed confidence in Sir Thomas Bouch as a bridge designer, put an end to any further progress ; and on re-consideration of the whole proposal it was decided to abandon any idea of erecting a railway bridge of the suspension type. The four railway companies concerned with the project instructed their consulting engineers, Messrs Barlow, Harrison and Fowler, to go into the whole problem and to report first whether a bridge at this site was a feasible proposition, and secondly, if so, what type of bridge would be the best. They were also to inquire as to whether tunnels could be constructed, and if so whether they would be better than a bridge. The report was in favour of a bridge at the Queensferry site, and the design submitted by Messrs Fowler and Baker for a continuous girder bridge of the cantilever and central girder type was, after certain modifications, approved, and the railway directors were recommended to adopt it as the most satisfactory solution of this great and difficult problem.

The directors, after consulting the Board of Trade, adopted the proposal, appointed Messrs Fowler and Baker as engineers to carry the proposal into execution, and an Act of Parliament authorising the work was obtained in July 1882.

The following is a brief description of the whole structure. At the south end are four granite masonry arches which finish at the abutment for the south approach viaduct. This viaduct consists of ten girder spans supported on granite piers, the last girder resting on the south cantilever end pier. At the north end there are three similar granite arches and five girder spans, while the bridge proper consists of three double cantilevers and two central connecting girders. The length of the cantilever portion of the bridge is 5349 feet 6 inches, the south viaduct is 1978 feet long, and the north viaduct 968 feet 3½ inches, the total length of the structure being 8295 feet 9½ inches. The two great spans are 1710 feet from centre to centre of the vertical columns, the cantilever portions being 680 feet long each and the central girder 350 feet long. The rail level is 157 feet above high-water level, and this gives a clear headway for shipping of approximately 157 feet in height for a total width of 500 feet in the centre of each channel.

The contract was signed in December 1882, and a start was at once made with the preliminary work; and on 21st January 1890 two trains used for testing purposes entered side by side upon the bridge from the south side, their total weight being 1800 tons. A detailed account of the design and construction of this great bridge was published by *Engineering* in February 1890.

T. H. B.

JAMES NASMYTH.

V

ZOOLOGY

IN Scotland the study of animal life lingered in the waking. In early days, up to the sixteenth century, it merely shared a place, neither distinctive nor obtrusive, in the general descriptions of the country and its inhabitants; and even in the seventeenth century, while England, under the guidance of Moufet, Christopher Merret, Willughby, Martin Lister and John Ray, had encompassed a great part of the fauna, Scotland lingered, though Johnston's *Historia Naturalis* (Frankfort, 1649–53) may have gained inspiration from his sojourn at the University of St. Andrews.

What part did Edinburgh play in the revival of zoology that reached Scotland from the Continent in the latter years of the seventeenth century? It made a good lead with Sir Robert Sibbald (1641–1722), an Edinburgh man born and bred, a student of its University, and a practitioner in the town. His *Scotia Illustrata* (1684) made a first attempt to tabulate as a whole the fauna of the country, and his *Phalainologia Nova* (1692) described for the first time the Cetacea of British seas. But apart from his direct contributions to knowledge, Sibbald's scientific activities gave a strong impetus to natural science in Edinburgh.

Edinburgh has long been a capital city, and this has had a definite influence upon the development of natural science; for the tendency in a capital is towards the foundation of institutions, and to Edinburgh's institutions, rather than to the spasmodic efforts of genius, we must look for the steady growth of knowledge. The clearest glimpse of the city's influence upon the progress of zoology, therefore, is to be gained by delving in the history of her University and Colleges, of her learned societies, her museums and her zoological parks, and not least of her printing presses. These institutions are not all of equal significance—some aim at pushing forward the boundaries of knowledge, some at the dispersal of knowledge already gained—but all have shared in promoting the advance of zoological learning.

For close on two hundred years after the founding of the "Town's College," in 1583, no attempt was made to teach zoology as such till, in 1767, the Chair of Natural History was established. But the early incumbents, Robert Ramsay, John Walker and Robert Jameson, left little direct mark upon zoological science, though Walker included amongst his *Essays* a generalised account of the *Mammalia Scotica*, and Jameson, whose interests leaned towards geology, gave a strong impulse to all branches of natural history by his editorship of the *Edinburgh Philosophical Journal*, his founding of the Wernerian Society and his energy in adding to the collections of the Museum of the University.

With the appointment of John Fleming (1785–1857) to the new Chair of Natural History in the Free Church College in 1845, and of Edward Forbes (1815–1854) to that in the University in 1854, zoological teaching in Edinburgh entered upon a new phase, for both men were naturalists, disciplined in the taxing school of detailed classification, but possessing the broad view that builds facts into truths. Fleming's *British Animals* (1828) greatly furthered investigation by its conciseness and comprehensiveness, and his simple *Philosophy of Zoology* (1823), which gained for him a European reputation, aimed at converting the study of animals from the fallacies of external resemblance to the deeper truths of general organisation and function. Edward Forbes's highest achievement lay, not in his masterly *British Starfishes* (1851), nor in the additions he made to the known faunas of many seas, but in the fine grasp of wider truths which enabled him to lay a broad foundation for the study of life in the sea, upon which subsequent investigators have not been slow to build the modern science of Oceanography (see next section).

After a tenure all too short, Forbes was succeeded in 1855 by George J. Allman (1812–98), whose bent lay towards detailed research, and whose many contributions to the systematic knowledge of the Hydrozoa, in particular his monograph on the *Gymnoblastic Hydroids* (1871–72), brought to a climax the work of an enthusiastic group of Scottish marine zoologists, and formed landmarks for investigators of hydroid zoophytes the world over. Allman resigned the Chair in 1870, and his successor, Wyville Thomson (1830–82), was a man of different stamp. Again the influences broadened and a persistent and organised search began after facts which would lead to the discovery of wide truths of animal distribution in the sea and, it was hoped, might give the clue to the ancestry of marine animals. Although he did much for zoological science by systematic researches on Echinoderms and by the investigation of British seas, Thomson will be best remembered for his organisation and successful conduct of the greatest scientific voyage ever planned—the "Challenger" Expedition of 1872 to 1876 (see under Oceanography). The present occupant of the Chair of Natural History in the University, J. Cossar Ewart, appointed 1882, in spite of an early bias to fishery investigation, has forsaken the maritime tradition which had laid hold of Forbes and his successors, and stands pre-eminent as a student of heredity, whose experiments on a large scale (see, for example, *Penycuik Experiments*, 1899) have thrown fresh light on the theory of telegony and kindred problems of the breeder.

Two recent developments in University teaching promise to have a far-reaching effect upon zoology in Edinburgh—the founding in 1919 of a Chair of Zoology concerned particularly with invertebrate animals, to which J. H. Ashworth, well known for his works on *Xenia, Arenicola,* giant nerve cells and other subjects, was elected; and the establishment of a Lectureship on Genetics, the main end of which is the conduct of experimental work towards practical ends.

While the naturalists followed each his set path, others of the professors of the University and Colleges made, from their own standpoints, occasional contributions to zoological science. Surgeons such as Sir Charles Bell, and anatomists like Monro *secundus* and Robert Knox, made excursions into comparative anatomy, or like John Goodsir, John Struthers and William Turner added to our knowledge of the structure of the Cetacea and other creatures.

The research of a teacher is one thing and his teaching another. The value of the latter may be assessed in a way by his audiences, but its ultimate test lies in the achievements of his students. What effect, then, has the teaching of Edinburgh had upon zoological progress through the accomplishments of her pupils? It is not suggested that the University is the only influence to be reckoned in the moulding of a student's later record, but it is powerful in determining the general direction of advance, even where the effect is least admitted. Therefore, without assessing this influence or that, we proceed to glance at the zoological achievements of Edinburgh students.

Most distinctive of the product of the University is the series of naturalist travellers who have left her walls to gather knowledge in the ends of the earth. Some gathered nature knowledge by the way, their minds set on other pursuits; amongst these were James Bruce (stud., 1747), Mungo Park (M.D., 1793), and William Balfour Baikie (M.D., 1847), naturalist on the Niger Expedition of 1854, all in Africa; William Scoresby (1806–9) in the Arctic regions; and Alexander Dalrymple (1737–1808, educated at Haddington) in the Southern Seas. But to others natural history was a chief end, and they added many pages to the book of zoological knowledge. The Franklin expeditions were staffed by Edinburgh naturalists: Sir John Richardson (M.D., 1816), surgeon and naturalist on the expeditions of 1819–22 and 1825–27, and leader of the Franklin search expedition of 1847–49, described many of the collections of these expeditions, and contributed largely to the *Fauna Boreali-Americana* (1829–37); while H. D. S. Goodsir, naturalist on the expedition of 1845, lost his life with his leader on that ill-fated voyage. The ocean laid strong hold on the imagination of Edinburgh students. John Macgillivray (med. stud., 1840–42), sailed for Torres Straits and the Eastern Archipelago in 1842 as naturalist on the "Fly," and his life was made up of a succession of exploring expeditions. In 1846 he became naturalist on the "Herald," along with Thomas Edmondston, and, leaving the vessel in 1855 at Sydney, he spent the remainder of his days voyaging and exploring amongst the Australasian islands. Charles Darwin (nat. sc. stud., 1825–27) set out to circle the world in the "Beagle" in 1831, and the *Journal* and other notable works issued from that memorable voyage. John Murray's long scientific labours culminated in the North Atlantic expedition of the "Michael Sars" in 1910, of the zoological value of which a foretaste has been given in his joint work with Dr Johan Hjort, *The Depths of the Ocean* (1912); and last of a noble succession of ocean travellers, William Spiers Bruce (med. stud., 1887–92), who has laboured in both Arctic and Antarctic regions and who led recent Antarctic voyagers by his naturalist cruise on a whaler in 1892, has by his "Scotia" Expedition (1902–4) added perhaps more than any other to our knowledge of the animal life of the far southern Atlantic and western Antarctic seas. Several students have done good service by biological expeditions aiming at the investigation of definite problems: of such I need only mention J. Graham Kerr's South American explorations, and Nelson Annandale's surveys of the peninsula of Siam and of typical Asiatic lakes.

Outstanding as has been the influence of Edinburgh students on the development of oceanic zoology in a wide sense, their industry and insight has furthered many another branch of the science. Before the close of the eighteenth century, Alexander Roxburgh (1759–1815) had made an important contribution to the economic side by his discovery regarding the colouring matter of the "lacoa" insect of India; and modern fishery research both here and abroad owes much to W. C. M'Intosh, D'Arcy W. Thompson, T. A. Wemyss Fulton, W. L. Calderwood, and J. D. F. Gilchrist. The investigators who have aided in unravelling the systematic and morphological relationships of animals are far too numerous to mention, and I would only cite as examples of their labours Robert Grant's (M.D., 1814) work on Sponges, William Baird's (m. stud., *c.* 1820) *British Entomostraca*, Charles Darwin's *Monograph of the Cirripedia*, W. C. M'Intosh's researches on Marine Annelids, those of W. A. Herdman on Tunicates, J. Arthur Thomson on Alcyonaria, J. Graham Kerr on Lepidosiren, J. P. Hill on the embryology of the Monotremes and Marsupials, and of David Sharp on Insects. Animal physiology at the present day is well represented by F. H. A. Marshall, economic entomology by R. S. M'Dougall. The extent of the Edinburgh influence on the development of Zoology may be gauged from the remarkable fact that each of the four old-established Chairs of Natural History in the Scottish Universities has been long occupied by an Edinburgh student—St. Andrews, W. C. M'Intosh and D'Arcy W. Thompson; Edinburgh, J. Cossar Ewart; Aberdeen, J. Arthur Thomson; Glasgow, J. Graham Kerr; and among others born and trained in Edinburgh we think of such distinguished teachers as W. A. Herdman in Liverpool, J. P. Hill in London, and W. A. Haswell in Sydney.

It is given to few men to illumine the thought of their fellows by focusing the light so that new fundamental truths spring into view or to gather scattered truths into a unified whole, but Edinburgh contributed to the training of Erasmus Darwin (stud., 1754) and of Charles Darwin (1809–1822), the former of whom, laying stress on the power of heredity, environment, habit and function to modify the characters of species, paved the way for those searching generalisations of his grandson which revivified the study of natural science. Here also must be reckoned such works of general import as *The Evolution of Sex* (1889) of Patrick Geddes and J. Arthur Thomson, the latter's *Heredity* (1909) and *System of Animate Nature* (1921), and D'Arcy Thompson's *Growth and Form* (1917).

The influence of the Societies upon the progress of zoology has been very different from that of the University. The University field is dominated in successive periods by the individuality of the professor for the time being; in each period the outlook changes, and progress becomes a series of disjointed movements—a discontinuous evolution, differing in the span as well as in the direction of its leaps. But a "Society" is more stable; tradition, embodied in a constitution and in a body of councillors, fixes the direction—the evolution is progressive and continuous. Apart from this general attitude towards progress, the importance of the societies lies in their having gathered and held together bodies of non-professional zoologists whose researches they have encouraged and in some measure directed, and in their affording means for the publication and distribution of knowledge gained. Especially valuable has been the influence of the Royal Physical Society and the now defunct Wernerian Society, in that they have kept in view the encouragement of newly fledged workers, many of whom have made their first flight in the pages of the journals of these societies. An indication of their usefulness may be gained by the perusal of some of the names of contributors.

During its brilliant course, from 1808 till 1858, when it became incorporated in the Royal Physical and the Botanical Societies of Edinburgh, the Wernerian

Society numbered amongst its contributors on zoological subjects such men as John Fleming, the Arctic explorers W. Scoresby and Sir John Richardson, George Montagu, Patrick Neill, R. Jameson, W. Macgillivray, William Swainson, P. J. Selby, James Wilson, Robert Knox, T. S. Traill, W. E. Leach, R. E. Grant, and R. Parnell; and these men by their labours added very materially to our knowledge of the anatomy, habits and distribution of British and foreign mammals, birds and fishes, as well as of worms and other invertebrates.

Even more striking has been the record of the Royal Physical Society, which, founded in 1771, celebrates this year its hundred and fiftieth session: for its vitality (it absorbed between 1782 and 1858 seven languishing societies), and its predilection for zoology since its first "Physico-Chirurgical" love faded with the dropping of the latter half of its name, have contributed to intensify its zoological influence. In earlier days its pages witnessed to the zoological work of Fellows whose names have found a place on the roll of scientific progress: Hugh Miller, John Fleming, Strethill Wright, C. W. Peach, Andrew Murray, whose *Distribution of Mammals* (1860) was a pioneer work of significance, John Alexander Smith, Robert Gray, J. A. Harvie-Brown, John Clelland, John Goodsir, Edward Forbes, John Reid, James Young Simpson, Wyville Thomson, W. B. Carpenter, William Turner, and R. H. Traquair; whilst amongst present-day Fellows who have guided its fortunes or contributed to its zoological output, I need only mention, out of many, William Evans, J. Cossar Ewart, J. Graham Kerr, J. Arthur Thomson, O. C. Bradley, Arthur Robinson, J. H. Ashworth, W. A. Herdman, W. Evans Hoyle, B. N. Peach, J. F. Gemmill and Thomas Scott.

Most powerful of the Societies is the Royal Society of Edinburgh (instituted 1783), amongst the wide interests of which zoology holds an important place. From its foundation the Royal Society wielded a strong influence on the development of natural science, for to it was largely attributed the marked tendency in the early years of the nineteenth century of Scottish thinkers to forsake metaphysical speculation and to seek truth by way of the physical and natural sciences. As an example of its recent zoological work, I instance only a remarkable series of papers describing the vast collections made by the Scottish National Antarctic Expedition.

Other naturalist societies in Edinburgh, capable and enthusiastic, have done not a little in keeping alive amongst their members an interest in zoological studies.

In general the progress of zoology has been led along narrower paths by the museums than by the learned societies, for the limitations imposed by the collection and storing of animals have tended to drive museum research into systematic channels. But on the other hand museums perform a work for zoology which scarcely comes within the scope of the great societies: they become more and more the middlemen between the researcher and the public, the interpreters of scientific progress for the simple observer and the plain man. Museum zoology has had a long run in Edinburgh. In the seventeenth century Sir Andrew Balfour arranged his museum in the city, and Dr William Hunter, the founder of the Hunterian Museum of Glasgow University, was an Edinburgh student. But zoological museums proper began with the University collection, founded in 1812, the "Royal Museum of the University," a repository of much good material. This, in 1855, was transferred to Government control, and formed the zoological collections of the museum successively known as the Industrial Museum, the Museum of Science and Art, and now the Royal Scottish Museum. Here are housed many important zoological and palæontological collections, among which may be mentioned the Dufresne collection (purchased in 1819 for £3000), the collections of Edward Forbes and Hugh Miller, many of Wyville Thomson's specimens, and the collections made by the Scottish National Antarctic

Expedition, presented through the generosity of W. S. Bruce, as well as fine collections of fossil fishes selected by R. H. Traquair, of British birds collected by W. Eagle Clarke, and of fossil invertebrates. These include many type and figured specimens.

Apart from furnishing materials for research, the Royal Scottish Museum has itself made notable contributions to zoology, in particular through the works of R. H. Traquair on fossil fishes, of W. Eagle Clarke on ornithology and especially on the migrations of birds, of P. H. Grimshaw on Diptera, and the writer has taken part in the investigation of the Hydrozoa and of the development of the Scottish fauna.

In referring to the influence of Edinburgh Museums one cannot pass over the activities, first in the Royal Museum of the University and later, as Conservator (1831–41), in the Museum of the Royal College of Surgeons, of William Macgillivray, whose *History of British Birds* (1837–52) is still regarded as a work of outstanding merit.

Akin to the museums in the greater part of its work, largely systematic and faunistic, was the first Scottish Marine Station—a floating laboratory, the old "Ark" which at the instance of Sir John Murray was in 1884 anchored in the Firth of Forth, west of Granton. The Forth Marine Station is an old story now: its anchorage is a mound of cinders, and the "Ark" itself was taken to the Clyde to become the forerunner of the present station at Millport, but it and Murray's yacht "Medusa" will be remembered for the work accomplished there by a band of enthusiastic zoologists which included J. T. Cunningham, W. Evans Hoyle, J. R. Henderson and W. A. Herdman.

A review of Edinburgh's zoology would be incomplete were no reference made to the influence of the printing presses. In the eighteenth and early nineteenth centuries there issued from them a steady flow of zoological information, sometimes in serial form, as in the *Edinburgh Philosophical Journal* (1774–1834), sometimes as monographs, as Smellie's laborious *Philosophy of Natural History* (1790 and 1799), Patrick Syme's *Treatise on British Song Birds* (1823), John Murray's *Experimental Researches* (1826), Stark's useful *Elements of Natural History* (1828), Sir J. G. Dalyell's *Powers of the Creator* (1851), and *Rare and Remarkable Animals of Scotland* (1847), or the fine series of forty volumes, *The Naturalist's Library*, edited by Sir William Jardine. At other times translations of landmarks in zoological literature held the field, as Robert Kerr's *Animal Kingdom or Zoological System of Linnæus*, his *History of Quadrupeds and Serpents*, or Macgillivray's adaptation of the *Animal Kingdom* of Cuvier, published with his *Edinburgh Journal of Natural History* (1835–40). In more recent days the flood seems scarcely to have slackened, when we think of Symington Grieve's monograph on *The Great Auk*, William Evans's *Mammalia of the Edinburgh District*, Eagle Clarke's *Studies in Bird Migration*, and Harvie-Brown and Buckley's series of eleven volumes on the *Vertebrate Fauna of Scotland*. Edinburgh also has taken a leading part in the conduct of a magazine, the stored knowledge of which is invaluable to the student of Scottish animal life, the *Annals of Scottish Natural History*, which in 1912 resumed its earlier title of *The Scottish Naturalist*.

Though one Edinburgh "Zoo" has long since disappeared—it was established in the Trinity district in 1840—and another is still in its infancy, both have helped to stimulate an interest in animal life amongst the people. The old garden was on stereotyped lines, but the new park of the Zoological Society of Scotland on Corstorphine Hill has benefited by the experience of others, and in site and design promises to be amongst the foremost of the gardens in which natural beauty is united with the greatest possible freedom for its animal inhabitants.

To sum up the drift of these many activities in a brief answer to the question, What, then, are Edinburgh's zoological achievements ?

Lightly we pass over her efforts on behalf of popular zoology—the direct appeals of her museums, her zoological gardens, her popular natural history societies, and her printing presses—for such activities are common to many well-developed intellectual communities; and we turn instead to her original contributions to knowledge.

The bulk of her work has been faunistic, concerned with the collecting and cataloguing of the creatures in the immediate vicinity and in Scotland as a whole; and this is a normal development of local scientific activity, for the work lies ready to hand and offers scope for the play of limited leisure. With local faunistic progress I would associate in particular the names of the Wernerian and Royal Physical Societies, and *The Scottish Naturalist*.

But the faunistic work has traversed a wider field than that afforded by the local fauna, and collections from all parts of the world have been investigated by Edinburgh men. This wider field has involved a more intense study of systematics, and her contributions to systematic zoology, including a fine record of palæontological research, I would place second in the mass of Edinburgh's zoological output. And this also is a natural sequence, for the problems of systematic zoology form the ruck of the science, though in their solution lies the foundation of sound progress. Edinburgh has tended to follow two great driving lines in these branches of research—the exploration of the sea and its inhabitants, and the investigation of the fossil faunas of the geological succession. With comprehensive faunistic and systematic work I would associate the Royal Society of Edinburgh, the University, the Royal Scottish Museum, the "Challenger" and "Scotia" Expeditions, the Geological Survey, and many accomplished monographs elucidating particular groups of animals. In other branches of the science the mass production of Edinburgh falls short of that in systematics, but important work has also been accomplished in general morphology, in histology, in physiology, and in bionomics.

So much Edinburgh has achieved for the workaday progress of zoology, but still more she has done ; for flashes of her insight have illumined wide fields of science. Outstanding amongst these great ideas are Forbes's thesis on the zonal distribution of marine animals, Wyville Thomson's conception of the life and life-forces of the deep sea, Geddes and Thomson's theory that maleness and femaleness are expressions of alternatives in the regulated rhythm of sex, and, most far-reaching of all, Charles Darwin's theories of the evolution and the origin of species.

As a rule, however, Edinburgh, with truly Scottish practicality, has turned rather to the side of workaday investigation and detailed analysis than to synthesis and speculation ; but even this, in days when zoological speculations founded on too narrow bases are rife, is to be reckoned to her credit. Her achievement lies in that, beyond her few great ideas, she has done her full share in the hewing of the stones of the temple.

J. R.

VI

OCEANOGRAPHY

OCEANOGRAPHY is the science of the sea in all aspects, and Edinburgh is the birthplace and the home of modern Oceanography. The foundations upon which this branch of science has been recently built can be traced back to very early times —to the voyages of the Phœnicians, to the explorations of the seamen of the fifteenth and sixteenth centuries, such as the men of Henry the Navigator, and Magellan who attempted to sound the Pacific in 1521; but in the modern development of Oceanography which led in the latter part of the nineteenth century to its recognition and establishment as an organised body of knowledge Edinburgh men played a leading part. It is impossible in a short article such as this to trace every stage and mention all worthy names, but fortunately there are three notable men, all closely connected with our city and our University, who may be selected as types of periods and methods of marine investigation during the nineteenth century. These leaders of our science are: Edward Forbes the naturalist and pioneer of shallow-water dredging during the earlier half of the century, Wyville Thomson the explorer of the deep-sea and scientific leader of the "Challenger" Expedition, and John Murray who continued the work of Thomson and guided research in the last quarter century into deeper and more fundamental problems of the Ocean and brought the science practically to its present position and outlook.

Edward Forbes (1815–54) was of Scottish descent, but was born in the Isle of Man, where his mother owned a small estate on the western coast of the island, opposite the fishing bank of Ballaugh. Here Edward Forbes commenced as a mere boy his marine biological studies and the accumulation of those collections and observations which afterwards formed the basis of his classic works on *British Starfishes* (1841) and *British Mollusca* (1853). He left home at the age of seventeen, and from that time onwards the whole of his short, strenuous life was devoted to science—and mainly to the science of the sea. He was a many-sided genius who produced an extraordinary volume of first-rate original work in marine biology and inspired advances in Oceanography which he did not live to see carried out.

After a short period of art-study in London he arrived in Edinburgh (1831) as a medical student, and there he remained for nine years. It is interesting to note that our three selected leaders in science were all students of medicine in this University, and not one of them graduated !

At Edinburgh Forbes was one of a group of brilliant young men of whom may be mentioned John Goodsir the great anatomist, Hughes Bennett the physiologist, Balfour the botanist, George Wilson the biographer of Forbes, and Sir Robert Christison—all afterwards professors in the University. This was clearly a stimulating and formative period in Forbes's life, definitely related to much he did later on and brightened by scientific fellowship which was maintained to the end.

About this time the naturalist's dredge for exploring the bottom of the sea was brought into prominence almost simultaneously in several European countries—by H. Milne-Edwards in France in 1830, by Michael Sars in Norway in 1835, and by Forbes in the Manx seas about 1832. Several summer vacations between 1832 and 1839 were spent in dredging the Irish Sea and exploring the fauna and flora of the Isle of Man, and we see the results in his first published book, *Malacologia Monensis* (1838), and in certain papers in the *Annals and Magazine of Natural History*. In 1839 he and Goodsir were dredging in the Shetland seas, with results which Forbes made known to the meeting of the British Association at Birmingham that summer with such good effect that the celebrated "Dredging Committee" of the Association was formed to continue the good work. Forbes and his British Association Dredging Committee may be said truly to have led on step by step to the "Challenger" and other expeditions of modern Oceanography.

Mr Robert MacAndrew, a Liverpool merchant and yachtsman interested in the Mollusca, during the last decade or so of Forbes's life frequently took him, Goodsir and others on important dredging expeditions round the British coasts. These expeditions were of immense importance from both faunistic and distributional points of view, and MacAndrew deserves our recognition and gratitude for the essential help he gave in these early explorations of the British seas. We find Forbes and Goodsir in their important paper *On Some Remarkable Marine Invertebrata new to the British Seas* (*Trans. R.S.E.*, xx, 1851) recording that the animals "were taken during a yachting cruise with our indefatigable friend, Mr MacAndrew, among the Hebrides in the month of August 1850."

All Forbes's later and more famous work in Marine Biology and Oceanography—work that extended from Hebridean and Scandinavian seas through the Mediterranean to the far Ægean—may be said to have sprung from his early work done as a lad in his home Manx waters, and on the shores of the Firth of Forth while a student at the University of Edinburgh.

In 1841 came the great opportunity of his life to make marine investigations in an interesting region outside the British seas and to extend his observations to greater depths. Captain Graves, then in command of H.M. surveying ship "Beacon" engaged on hydrographic work in the Eastern Mediterranean, offered Forbes the post of naturalist to the expedition, which was promptly accepted. The work, so far as Forbes was concerned, was partly on land and partly at sea, partly archæological and partly oceanographic; and one result was *Travels in Lycia,* by Forbes and Lieut. Spratt, in which the chapters on the Natural History of Lycia and the neighbouring seas are evidently the work of the former author. His dredgings in the Ægean gave great results and led to the well-known and much-discussed views on "zones of life in the sea" which will always be connected with his name. He dredged successfully to a greater depth (230 fathoms) than any one had done before, and to his surprise brought up living starfishes and other animals from 200 fathoms. He writes that the shellfish from the deeper water all belong to types only known in the fossil condition, and that so far he is the only zoologist who has seen them alive. His Report on the distribution of animals in the Ægean Sea, presented to the British Association at Cork in 1843, was, a contemporary tells us, a most important and philosophic summary of the facts, which at once raised the author to a high rank among living naturalists. He defined in the Ægean eight zones of depth characterised by peculiar assemblages of animals, and he "conjectured that the zero of animal life would probably be found somewhere about 300 fathoms"—so he named the region below that the "Azoic zone"—a conclusion which has since been found to be erroneous. The British Association gave him congratulations and encouragement and the material support of a grant of £100 "to be expended in comparing the fauna of the Red Sea with that of the Mediterranean." Forbes thereupon planned a more extended expedition to more tropical waters, from which most interesting results might have been expected. This expedition was postponed on account of a severe attack of fever, and then abandoned when he was recalled to London in 1842 to become Professor of Botany in King's College.

He then became successively Curator of the Geological Society and Palæontologist to the Survey, and was engaged on work which occupied some of the best years of his life and had a distinct bearing upon oceanographical problems. At this time he was what he called a "zoo-geologist," working on the border-line of the two sciences and throwing light on both, bringing zoological knowledge in regard to the animals he had to deal with as fossils to bear upon geological problems, and showing, on the other hand, how geological changes in the past help to explain the distribution of animals and plants at the present day. In some respects this was the finest and most original work he ever did, and as an example of his geological work of primary oceanographic importance we may take his celebrated paper *On the Connection between the Distribution of the Existing Fauna and Flora of the British Isles and the Geological Changes which have affected their Area* (*Memoirs of the Geological Survey*, vol. i, 1846), now universally regarded as a classic on the subject. He recognised that the origin of the fauna and flora of a country could not be solved from biological studies alone, but required in addition the evidence supplied by geology in regard to former changes in climate, land and water. He accounted, for example, for the five sub-floras which he defined, as due to successive migrations from neighbouring lands previous to the isolation of the British Isles from the mainland of Europe. The fauna of our seas he showed presented distinct northern and southern relations. This is clearly seen both amongst the invertebrata, such as molluscs, and also amongst fishes. In discussing these relations, one of the many interesting points that Forbes demonstrated was the presence of "Boreal Outliers" or assemblages of northern species occupying the deeper areas of about 80 to 100 fathoms that occur here and there on the west of Scotland. These he regarded as portions of the original northern fauna which formerly occupied our seas and had retreated northwards when the climate became more genial subsequent to the glacial epoch, leaving these colonies isolated in the deeper holes. Forbes's theories on distribution and on the origin of the British fauna and flora, even if in part erroneous, were a notable contribution to the subject and far in advance of anything known at the time, and had an important influence on the history of science. About 1850 Forbes prepared his remarkable map of distribution of marine life over the oceans of the world, and of homoiozoic belts, which was probably the first attempt to divide the oceans into provinces on scientific grounds.

There is no space to refer in detail to this and others of his writings and lectures, which with his more matter-of-fact descriptive works form a wonderful output both in quantity and quality for a man to have produced who died before reaching the age of forty, about six months after he had attained to the goal of his ambition—the Chair of Natural History in the University of Edinburgh, on the death of his old teacher, Jameson, in 1854. It is reasonable to suppose that had he lived he would have made Edinburgh the greatest centre of marine biological work in Europe. That was evidently the opinion of his contemporaries. It is on record that he was worshipped by the men, old and young, who attended his first and only course of lectures in Edinburgh. They spoke of the wonderful influence, charm and fascination that Forbes exercised on all who came in contact with him, and of the gloom and consternation which spread over the University when it was realised that he would never again meet his class. He was the most original, brilliant and inspiring naturalist of his day, with a broad philosophic outlook over nature and a capacity for investigating border-line problems involving several branches of science—he was in a word a pioneer of Oceanography and the spiritual ancestor of men like Sir Wyville Thomson and Sir John Murray.

We now pass from the period of the early marine field-naturalists to that of the later Oceanographers of the nineteenth century. If Forbes was the pioneer of shallow-water dredging, Wyville Thomson played a similar part in regard to the exploration of the depths of the ocean. His name will go down through the ages as the leader of the famous "Challenger" Expedition, by far the most important scientific deep-sea exploring expedition of all times.

Between Edward Forbes and Wyville Thomson there are many links. Both were naturalists in the widest sense, with an extensive knowledge of the natural sciences and a great appreciation of nature in all its aspects. Each occupied at the end of his life the Chair of Natural History in the University of Edinburgh, though neither was given time to develop the great school of marine biology which might have been expected from such men in such a place had opportunity permitted. Forbes was only fifteen years the senior, and was at the zenith of his fame—publishing epoch-making views on the distribution of living things in the sea—at the time when Thomson entered the University of Edinburgh, and no doubt these views would arrest the attention and guide the thoughts of any keen young student of the natural sciences. It was Forbes who, on a basis of observations which were then thought to be sufficient, but are now known to have been exceptional, placed the zero of life in the sea at 300 fathoms or thereabouts, and it was Wyville Thomson more than any man who proved that Forbes's views were in this particular erroneous and that many and varied living things inhabit the greatest depths of the ocean.

Charles Wyville Thomson (1830–82) was born at his ancestral country house of Bonsyde, near Linlithgow, and was in every sense, by ancestry and by education, a son of Edinburgh. While a medical student he observed and collected marine invertebrates along the prolific shores of the Firth, and like many other intelligent students in Edinburgh he joined the Royal Physical Society—which despite its name is a society of Natural

History—and for a couple of years filled the office of Secretary, surely one of the youngest on record. Fortunately for Oceanography, after about three years of study ill-health caused the young naturalist to give up all idea of the medical profession and to turn his attention definitely to Science as his life-work. He left the University in 1850, without taking a degree, but his ability and reputation were such that he made rapid progress and filled in succession Chairs of Botany, Geology and Natural History in Cork and Belfast, and this wide range of interest and of knowledge was, of course, of immense advantage in his great work that was to come in exploring the oceans.

It is interesting to trace how Thomson's earliest investigations on fossils led on by successive steps to the novel and fruitful field of deep-sea exploration. His palæontological observations suggested work on living Crinoids, and that led to his investigation of the larval stages of the Rosy Feather-Star (*Antedon rosaceus*) along with Dr W. B. Carpenter during summer vacations at Lamlash Bay, Arran. And then the news that a strange new stalked Crinoid (*Rhizocrinus lofotensis*), related to the fossil Apiocrinidæ and resembling the larval form of *Antedon*, had been found living in northern seas induced him in 1866 to visit Michael Sars at Christiania and examine for himself the remarkable collection of rare animals that G. O. Sars, the son, had brought up from deep water (over 300 fathoms) in the Lofoten fjords. Thomson was very naturally struck by their novelty and deep interest, and by their resemblance to and bearing upon some of the extinct animals of former geological periods and especially of the Chalk.

Thus inspired, he urged his friend Carpenter, with whom he was then working at the later development of *Antedon*, to join him in endeavouring to promote an expedition to explore the deep waters of the Atlantic. Carpenter's powerful advocacy induced the Council of the Royal Society to use their influence with the Hydrographer, with such success that the Admiralty placed first one and then another small surveying steamer at the disposal of a committee of scientific experts, for expeditions under the leadership of the two enthusiasts. After the first summer a third naturalist of European fame, Dr Gwyn Jeffreys the conchologist, joined Carpenter and Thomson in conducting the practical work at sea; and the account of how in 1868 H.M.S. "Lightning" and in 1869 and 1870 H.M.S. "Porcupine" were equipped by the Admiralty and sent out to explore the depths from the Faroes in the north to Gibraltar and beyond in the south is given in full detail in Wyville Thomson's book *The Depths of the Sea*, which may be regarded as the first general text-book of Oceanography. It was published just as the "Challenger" Expedition was leaving England in 1872, and so gives a statement of matters and opinions up to that important point in the history of the science of the sea.

In the summer of 1868, on that "cranky little vessel" the "Lightning," in the rough seas of the North Atlantic, they dredged down to 600 fathoms; and in 1869 on the "Porcupine," a more seaworthy ship, they got successful hauls from the great depth of 2435 fathoms. Incidentally we may remark that another Edinburgh professor—Fleeming Jenkin, the engineer—while repairing a cable in the Mediterranean, in 1860, found several kinds of sessile animals, including a deep-sea coral, attached to the broken cable at a depth greater than 1000 fathoms, and therefore much beyond the supposed "zero" of Forbes. During the "Lightning" and "Porcupine" Expeditions sixteen hauls of the dredge were taken at depths beyond 1000 fathoms and two in depths greater than 2000 fathoms, and in all cases life was found to be abundant at the bottom.

In the final chapters of *The Depths of the Sea* we find a discussion of such highly important and controversial oceanographic matters as Deep-Sea Temperatures, the Gulf-Stream and the Continuity of the Chalk—especially important as representing the author's views just previous to the explorations of the "Challenger."

Wyville Thomson, the active organiser and leading spirit of these new and successful investigations, succeeded Allman in 1870 as Professor of Natural History in Edinburgh. Had time and strength permitted he also might have been expected to develop a great school of Marine Biology in connection with his University, but larger schemes farther afield almost immediately claimed his attention.

The undoubted success of the preliminary expeditions in the "Lightning" and "Porcupine" encouraged Carpenter and Wyville Thomson, again through the Council of the Royal Society in co-operation with a Committee appointed by the Council of the British Association, to induce the Government to equip a deep-sea expedition on a really grand scale to explore and make known the conditions of life in the great oceans. This resulted in the famous circumnavigating expedition in H.M.S. "Challenger," and Wyville Thomson as the chief originator of the expedition was appointed Director of the civilian scientific staff on board. Two others of that staff, J. Y. Buchanan and John Murray, were also representatives of Edinburgh University.

It has been said that the "Challenger" Expedition will rank in history with the voyages of Vasco da Gama, Columbus, Magellan and Cook. Like these it added new regions of the globe to our knowledge, and the wide expanses thus opened up for the first time—the floors of the oceans—were vaster than the discoveries of any previous exploration.

The "Challenger" sailed in December 1872 and returned in May 1876, and during these three and a half years she traversed nearly 70,000 miles in the Atlantic and Pacific Oceans and penetrated as far south as the Antarctic ice barrier. Soundings and dredgings were taken at 362 stations, and enormous collections such as the scientific world had never seen before of marine organisms large and small, and of samples of bottom deposits and of water from all depths and all latitudes, were brought home for detailed investigation. As Sir Ray Lankester has said, "never did an expedition cost so little and produce such momentous results for human knowledge," and Edinburgh may fairly claim a share in the glory reflected from the expedition led by her famous Regius Professor of Natural History.

On the return of the expedition Wyville Thomson was appointed Director of the "Challenger Expedition Commission," located in Edinburgh, for the purpose of seeing to the investigation of the vast collections, and the publication of the results; and from that time onwards for about twenty years Edinburgh was the centre of oceanographic research and the Mecca towards which marine biologists from all over the world turned to inspect the novelties of the wonderful collections and to discuss results. In the practical work, which was centred in the "Challenger" Office and in some of the laboratories of the University, in addition to the staff of the Commission other well-known Edinburgh men of science, such as Sir William Turner, Professor P. G. Tait, Professor Crum Brown, Professor Chrystal, Sir Archibald Geikie and others, played a leading part. The researches were now by no means confined to Biology, but ranged over a wide field in the physics, geology and chemistry of the sea. Tait's work on the pressure errors of the "Challenger" thermometers, and on the physical properties of sea-water, Buchanan's report on the specific gravity of the water samples, Gibson's analysis of the manganese nodules, and Buchan's reports on atmospheric circulation and on oceanic circulation were all notable contributions to the subject by Edinburgh men outside the biological group at the "Challenger" Office.

It is unfortunate that the man of science has so frequently to make a choice between the necessary work of administration and original research. Sir Wyville Thomson was given little time for either. In the few years of work that remained before his health gave way, he was so constantly occupied with his many and varied duties as Director of the "Challenger" Commission and editor of the Reports, that there was no time for the original work he had planned to do in connection with the collections of Stalked Crinoids and of Hexactinellid Sponges—the two groups he had reserved for his own investigation and upon which he was an acknowledged authority.

During this time at home Wyville Thomson published his preliminary account of the general results of the expedition in two volumes, entitled *Voyage of the "Challenger"* (*The Atlantic*), which were to have been followed by companion volumes on the Pacific that unfortunately never appeared. *The Atlantic* is a most readable work, full of observations on the botany, geology and antiquities of the places visited as well as on the marine biology and general oceanography of the cruise. The conclusion at which Wyville Thomson arrived (1877) from a consideration of deep-sea and shallow-water faunas was (*Atlantic*, p. 331): "It would seem that the enormous pressure, the utter darkness, and the differences in the chemical and physical conditions of the water and in the proportions of its contained gases depending upon such extreme conditions, do not influence animal life to any great extent."

Even after his health began to give way, he arranged for and directed, if he did not actually conduct, a very important subsidiary expedition for the purpose of investigating further the very remarkable conditions of temperature and fauna which had been noticed in the Faroe Channel during his earlier cruises in the North Atlantic.

Carpenter and Wyville Thomson during their preliminary investigations in the "Lightning" and "Porcupine" had found that the Faroe Channel between Cape Wrath and the Faroe Isles was abruptly divided into two regions having very different conditions—a "cold" and a "warm" area, only about one hour's sail apart, but differing in temperature by about 15° F. The temperature of the water at the surface and down to a depth of 200 fathoms is much the same in the two areas; but in the "cold" area to the north-east the temperature is about 34° F. at 250 fathoms and about 30° F. at the bottom in 640 fathoms, while in the "warm" area which stretches south-west from the line of demarcation the temperature is 47° F. at 250 fathoms and 42° F. at the bottom in 600 fathoms. The warm area was found to have 216 species while the cold had 217, and of these only 48 species were common to both.

Wyville Thomson (see *Nature*, 2nd September 1880), from a consideration of the "Challenger" temperature results in various seas, came to the conclusion that the cold and warm areas of the Faroe Channel must be separated by a submarine ridge rising to within 200 or 300 fathoms of the surface and separating the deeper waters of the Atlantic and Arctic Oceans. He therefore addressed a letter in June 1880 to the Hydrographer of the Admiralty, pointing out these facts, and asking for the use of a surveying vessel for a few weeks for the purpose of sounding the Faroe Channel with the view of testing his prediction. That was the origin of the "Knight-Errant" Expedition conducted by Captain Tizard and Dr John Murray under the general direction of Wyville Thomson. The results (*Proc. R.S.E.*, xi, 1882) completely justified Thomson's prediction and showed that a ridge rising to within 300 fathoms of the surface runs from the north-west of Scotland by the island of Rona to the southern end of the Faroe fishing banks.

This was followed by a further expedition in H.M.S. "Triton" in the summer of 1882, again under Murray and Tizard, which was very fruitful of results. The discovery of two very different assemblages of animals living on the two sides of the "Wyville-Thomson Ridge"—Arctic forms to the north and Atlantic forms to the south—gives us a notable example of the effect of the physical conditions of the environment on the distribution of marine forms of life.

Wyville Thomson, however, did not live to see the "Triton" Expedition and the full results of the exploration of the submarine ridge which so appropriately bears his name. His health had been failing for several years, he resigned the Directorship of the "Challenger" Commission at the end of 1881 and died in March 1882 in his fifty-third year.

After his death it was fortunate for science and for the continuance of the influence of Edinburgh upon oceanographic research that Dr John Murray, who had been chief Assistant in the "Challenger" Commission since the return of the great expedition, was able and willing to take up the Directorship and bring the whole work to a most successful issue twenty years later. These two Scots share the honour of having guided the destinies of what is still the greatest oceanographic exploration.

John Murray was born at Coburg, Canada, in March 1841. He was of Scottish descent, and came as a boy to Scotland to complete his education. Like Forbes and Thomson, Murray started as a student of medicine at the University of Edinburgh, and again, like his two forerunners, gave up medicine for science and left without graduating. His first oceanographic expedition was in 1868, when he visited Spitzbergen and Jan Mayen and other parts of the Arctic regions on board a Peterhead whaler, on which, on the strength of having been once a medical student, he was shipped as surgeon. This voyage of seven months probably did much to confirm that interest in the phenomena and problems of the ocean which had been first aroused on his passage from Canada ten years before.

Nevertheless it was an odd chance that led to Murray's connection with the "Challenger." The scientific staff had already been definitely appointed when at the last moment one of the Assistant-Naturalists dropped out, and mainly on the strong recommendation of Professor Tait, in whose laboratory Murray was at the time working, Wyville Thomson offered him the vacant post —surely one of the best examples in the history of science of the right man being chosen to fill a gap.

In addition to taking his part in the general work of the expedition, Murray devoted special attention to three subjects of primary importance in the science of the sea, namely, the plankton or floating life of the oceans, the deposits forming at the bottom and the mode of formation of coral reefs. It was characteristic of his broad synthetic outlook on nature that in place of working at the anatomy of some group of organisms, however novel and attractive to the naturalist the deep-sea animals might seem to be, he took up wide-reaching general problems with economic and geological as well as biological applications. Each of these three main lines of investigation has been most fruitful of results both in his own hands and those of others. His plankton work has led on to those modern planktonic researches which are closely bound up with the scientific investigation of our sea-fisheries. His observations on coral reefs, in conjunction with the "Challenger" hydrographic results as to depths of the ocean and the presence of submarine volcanic elevations, resulted in his new and most original theory as to the formation of atolls in areas that were not undergoing subsidence (*Proc. R.S.E.*, x, 1880). His work on the deep-sea deposits resulted, after years of study and experiment in the laboratory in collaboration with the Abbé Renard, in the production of the monumental *Deep-Sea Deposits* volume in the "Challenger" series of Reports, which first revealed to the scientific world the nature and distribution of the varied submarine deposits and their relation to the rocks forming the crust of the earth.

These studies led, moreover, to one of the romances of science which deeply influenced Murray's future life and work, and that was the discovery of a valuable phosphatic deposit at Christmas Island in the Indian Ocean. He realised its economic as well as scientific value, and was able to convince the Government that this uninhabited volcanic island would be of value to the nation. The results of his exploitation of this discovery have been highly successful on both the scientific and the commercial sides, and Murray was able to show after some years' working that the British Treasury had already received in royalties and taxes from the island considerably more than the total cost of the "Challenger" Expedition.

During all his years of work at the "Challenger" Office, in addition to the business of editing the fifty large volumes of Reports, he was himself constantly investigating some of the more general problems of Oceanography and accumulating material for his two final volumes of the series—the *Summary of Results* (1894)—and many other papers and addresses to scientific societies. Whether all his views are accepted or not, they are all very stimulating and useful, and have given rise to much investigation and discussion in the history of Oceanography. His five great volumes are a monument to his memory. These and the other "Challenger" Reports which he edited record collectively the greatest advance in the knowledge of our planet since the great geographical discoveries of the fifteenth and sixteenth centuries.

It may seem curious that Edinburgh, so favourably situated on the shores of the Firth of Forth, and provided with the succession of eminent naturalists who have filled the University Chair of Natural History since the days of Jameson, has never possessed a Marine Biological Station. Murray at least made the attempt to supply this want. He had various schemes in his mind at different times, one of which was to acquire the island of Inchcolm and convert the ruins of the ancient monastery into the necessary laboratories and sea-water tanks. Eventually in 1884, along with his friend Robert Irvine, he acquired the lease of an old sandstone quarry near Granton into which the sea had broken some thirty years before, leaving it as a land-locked sheet of sheltered deep water which rose and fell with every tide. Here they moored a large canal barge upon which had been built a wooden house divided into chemical and biological laboratories, and called for obvious reasons "The Ark." In this floating biological station physico-chemical work was carried on for some years by Dr Hugh Robert Mill of Edinburgh, and biological work by Mr J. T. Cunningham. Eventually "The Ark" was towed through the Forth and Clyde Canal to Millport on the Cumbrae, and there it was beached as an annex of the Millport Biological Station. During the period when "The Ark" was at Granton, and later, Murray and Irvine turned out a good deal of joint work on the chemistry of the secretion of carbonate of lime by marine organisms, on the solution of carbonate of lime by the carbon-dioxide in sea-water, and on the chemical changes taking place in muds and other deposits on the sea-bottom. But Murray was by this time too busy a man and had too many other interests to be able to devote the constant attention that is necessary to the running of a successful biological station. He had larger and in some cases world-wide schemes of oceanographic research in his mind which demanded attention, and there was also the daily and ever-increasing work at the "Challenger" Office. The Granton biological station suffered also from its want of definite connection with a university laboratory.

But even in his busiest years at the "Challenger" Office Murray never gave up wholly his work at sea. The practical work that he did more or less periodically all the year round on the west coast of Scotland from his little steam yacht "Medusa" (38 tons) is a good example of careful planning and resolute carrying out in oceanographical research. The little vessel was fully equipped for biological and physical investigations in the neighbourhood of land, and during the years 1884 to 1892 she was almost continuously engaged in exploring the deep sea-lochs of the Western Highlands. Various younger men, such as Dr W. E. Hoyle and Dr H. R. Mill and the writer of this article, were associated with Murray in this work, considerable collections were made, and many scientific papers contributed to various journals have resulted from the cruises of the "Medusa."

One of the most notable of these is H. R. Mill's detailed description of the oceanographic characters of *The Clyde Sea Area* (*Trans. R.S.E.*, xxxvi–xxxviii, 1891–94). Another result was Murray's discovery in the deeper waters of Loch Etive and Upper Loch Fyne of the remnants of an arctic fauna—one of the "boreal outliers" of Forbes.

Sir John Murray's last oceanic expedition was a four months' cruise with Johan Hjort in the Norwegian investigating steamer "Michael Sars," in the North Atlantic, in the summer of 1910—a very notable achievement for a man in his seventieth year. The more general results have appeared in a volume entitled *The Depths of the Ocean* by Murray and Hjort, and the detailed scientific reports of the expedition are being published in a series of volumes by the Bergen Museum.

Finally, mention should be made of Murray's little book published in 1913 entitled *The Ocean, a General Account of the Science of the Sea*, which is undoubtedly the most concise and accurate and, so far as is possible within its small compass, complete account that has yet appeared of all that pertains to the scientific investigation of the sea. As his final contribution to science it is an appropriate summary of his life-work and will do much to spread the knowledge of his discoveries and to make his name widely known amongst intelligent readers of popular works on science.

The historically connected work of these three great pioneers in Oceanography—Edward Forbes, the dredger of shallow waters; Wyville Thomson, the explorer of the deep seas; and John Murray, who may be regarded as the founder of modern post-"Challenger" Oceanography—demonstrates the effect of Edinburgh men and ideas and work in advancing our knowledge of the science of the sea. And younger Edinburgh men have carried on and are carrying on the tradition. Notable among these is Dr W. S. Bruce, whose "Scotia" Expedition (1902–4) to the Antarctic is a remarkable example of what one man can do with the aid of private friends and a devoted staff of fellow-workers. This was the culmination of a long series of scientific explorations undertaken by Bruce in both Arctic and Antarctic seas. The "Scotia" was equipped with all the usual appliances for sounding and dredging, and after the return of the expedition to Scotland Bruce established in Edinburgh an Oceanographical Laboratory and Museum where the methods and results of oceanographic and especially Arctic and Antarctic research could be studied. Nearly thirty memoirs on the material brought back by the "Scotia" from the Antarctic seas have been published in the *Transactions of the Royal Society of Edinburgh* (vols. xli–lii, 1904–20), and most of these in collected form in the "Scotia" Reports, which, however, are still incomplete. As in the case of the "Challenger" series, the published memoirs include discussions on meteorology, magnetism and tides, and on the salinity, density and temperature of the ocean waters; and form a notable Edinburgh contribution to Antarctic Oceanography.

W. A. H.

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EDWARD FORBES.

VII

BOTANY

BOTANY (GENERAL). FORESTRY.

EDINBURGH'S service for the science of botany began as elsewhere concurrently with the development of medicine and has progressed with the rise and progress of the Edinburgh Medical School. In a small volume entitled *Makers of British Botany* (edited by F. W. Oliver : Cambridge Press, 1913) the story is told of the lives of the professors of botany in the Medical Faculty of Edinburgh from 1670 to 1887, and there is also given an account of the scientific atmosphere they severally created. Reference may be made to that work. Here it is only necessary to summarise shortly.

Towards the end of the seventeenth century the need of more methodical teaching in Materia Medica induced two Edinburgh physicians—(Sir) Robert Sibbald and (Sir) Andrew Balfour—to institute a garden for the cultivation of drug-plants in the vicinity of Holyrood, and they appointed James Sutherland (1639 ?–1719) as its keeper. Later this garden was moved to within the precincts of Holyrood and became the foundation of the Royal Botanic Garden of Edinburgh. Sutherland was subsequently appointed by the University to its Chair of Botany founded in 1673. In this way botanical teaching began in Edinburgh. Sutherland through troublous times managed his garden well. His place in relation to the development of scientific botany is that of pioneer in the teaching of systematic botany from living plants in relation to Materia Medica. His *Garden Catalogue*—now a work of some rarity—is the first record of a collection of cultivated plants in Scotland and tells us the plants which were recognised as indigenous at its date, and from it we can learn the time of introduction to Scotland of many alien plants and thus obtain a basis for gauging their influence on the native flora as we know it now.

Of Charles Preston (fl. 1696–1701) and his brother George Preston (fl. 1710–16), who succeeded Sutherland in turn in the University Chair, we know that they maintained the efficiency of the garden for its purpose in relation to Materia Medica and engaged in a considerable correspondence with botanists outside Scotland.

William Arthur (1680–1716), who succeeded Sutherland in the charge of the Botanic Garden only, was too much occupied as a Jacobite plotter to give much attention to botany.

From the date of the succession of Charles Alston (1685–1760) in the early eighteenth century to the responsibility of maintaining and developing botany in Edinburgh we find the City taking a prominent place in the botanical world of the period. Whilst Alston of necessity had to direct most of his attention to Materia Medica—and his comprehensive treatise on the subject reflects the best knowledge of his time—he occupied himself with practical and philosophical botanical questions of wide range: of the former, "Ventilation" and "Sanitation," in conjunction with the Southern vegetable physiologist, Stephen Hales, who interested himself in the subjects on behalf of the Admiralty, were subjects of investigation; of the latter, the newly published "Sexual System" of Linnæus attracted him, and no writer was more trenchant in opposition to it than Alston. His criticisms were based upon direct experiment. To disprove the necessity of development of the stamen for the development of fertile seed he cited cases of seed-production where no application of dust from the stamen was possible, thus early recognising conditions which puzzled botanists for many generations afterwards and until the explanation of apogamy was found. Already botany in Edinburgh was moving on physiological lines, and this feature of its development became strongly emphasised during the period of John Hope, who was Alston's successor.

In Alston the most vigorous opponent of the Linnean method had gone, and in John Hope (1725–86), Alston's successor, it found one to whose influence its rapid adoption in Britain owed much. It is this service that botanical historians have fixed upon as Hope's main distinction. But that really gives a false impression of his influence on botany. It has often been noticed as an interesting fact that the eighteenth century was remarkable for the publication in Edinburgh of many treatises on physiological botany by men who, beyond these publications, are unknown as botanists. There can be no doubt that these were a product of Hope's teaching. In Hope Scotland had a physiologist of originality and skill. He was not only informed of the work of physiologists in the south and abroad, but he had himself a gift for experimental work. Unfortunately he died suddenly, leaving incomplete a work on botany upon which he was engaged, and our knowledge of his physiological experiments is derived in the main from accumulated illustrative drawings which he evidently used in his teaching.[1] They give us a record of facts of plant physiology, some of which the botanical world generally only learned from other workers a hundred years afterwards. Had Hope placed his experiments and their results on record there can be no doubt that he would have been recognised as one of the great pioneers of vegetable physiology in this country. The catholicity of his work is attested by his dealing with such problems as "growth in length and thickness," "effects of light and of gravity," "movement of water," "healing wounds," and the like. This physiological work evidently exercised an important influence on the education of his time. Hope's pupils were many and they spread all over the country and far over the world. Apart from this special research work Hope through his prominent family position was enabled to do very great service to botany in regard to the better endowment and establishment of the Botanic Garden, and further by securing the separation of Materia Medica from Botany under separate professors. Thereby the Professor of Botany was able to devote himself entirely to his own subject.

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[1] See *Notes Roy. Bot. Gar. Edin.*, iv (1919), 241.

The professor who succeeded Hope was Dr Daniel Rutherford (1749–1819), known by name to many as the uncle of Sir Walter Scott. He was primarily a chemist, and apparently his interest in plants was mainly centred in them as objects for his experiments in relation to the chemistry of the atmosphere, at which he worked continuously (see pages 49–50).

Robert Graham (1786–1845), who succeeded Rutherford, was a systematic botanist of distinction and devoted himself to close investigation of the British flora besides laying himself out sedulously to the work of his botanical teaching. By the time of his occupancy of the post the contingent work of Professor of Clinical Medicine became strenuous to an extent which made much botanical research an impossibility.

Like conditions were dominant in the time of his successor, John Hutton Balfour (1808–84), whose influence upon the progress of botanical science has been mainly felt through his text-books and pupils and through his prescient introduction of entirely new methods of teaching made possible by the appearance of microscopes in more available form than hitherto.

Balfour's successor was Alexander Dickson (1836–1887), in the first rank as a morphological botanist.

The time following Dickson's tenure of office saw the loss of an opportunity which has affected profoundly botanical progress in Edinburgh. The Treasury was prepared to create in co-operation with the University a national research school of botany, and especially in its bearings upon rural economy problems, and at the same time was ready to provide equipment for the development of botanical teaching in the University. One condition of the partnership was to be that the fees of students benefiting by this expenditure by the Treasury should go to the Exchequer. This the Universities Commission refused to agree to. The scheme was not realised, and the equipment which was offered by the Treasury and which the University could not provide was lost to us. Thus evolution had to proceed on old lines, the Commission refusing even to recognise Bacteriology and Mycology as of sufficient importance to be subjects of special study.

Complete reconstruction of the Garden as a Government institution has been accomplished in recent years, and much work on methods of propagation of plants and upon the description and distribution of the plants of the Chinese flora sent home by former members of the Garden Staff. Just before the outbreak of war the Treasury had begun to provide improved laboratory and research accommodation, and these works are now in progress.

Of the building up of the Botanic Garden under these successive professors a detailed account will be found in the short *Sketch of the Garden* issued at the Garden for the use of visitors. In it will also be found a record of the principal gardeners who, as coadjutors, aided the professors in establishing its reputation.

With the development of the Royal Botanic Garden there synchronises a similar development round the Edinburgh centre of applied botany in its several aspects. The story of the progress of agriculture will be told elsewhere, as will be also that of forestry. Here it is germane to recall as an emanation from the Royal Botanic Garden in relation to the latter the founding of the Royal Scottish Arboricultural Society in 1854. In horticulture generally, noteworthy is the production of eminent practical gardeners and the evolution of a long line of enterprising firms devoted to horticulture and in a special manner to nurseries for forest trees as well as ornamental plants. In a long list of names it must suffice to recall a few of the more prominent.

Edinburgh took the lead in Scotland in the development of nurseries. The first two tree-nurseries in Scotland were established in Edinburgh about the beginning of the eighteenth century by Malcolm at "the Water Gate" and Gordon at "the Fountain Bridge." To these succeeded about 1770 a considerable one by Anderson and Leslie. Leslie contributed to render the larch popular—no small service—and was the first nurseryman to erect a greenhouse in Scotland. In the early days of the nineteenth century there were already established many nurseries of note—among others, the Leith Walk Nursery of the firm Dickson & Shankley, the Broughton or Adelphi Nursery of Messrs Dickson Brothers, the Jock's Lodge Nursery, and the Comely Bank Nursery. This strong representation of horticultural firms was a great asset in the formation of the Royal Caledonian Horticultural Society in 1809—the founder being Dr Andrew Duncan—which made an experimental garden in 1824—the pioneer garden of its kind in Britain—where much interesting practical work was carried out. To this period belongs Lawson (1794–1873), son of Peter Lawson, founder of Peter Lawson & Sons, Seedsmen—a firm which under the guidance of Charles became a power in the development of Scottish agriculture and horticulture. Among his introductions were the Italian Rye Grass, the Austrian Pine, and Lawson's Cypress. Botanists associate his name with the monumental *Pinetum Britannicum* and his *Agrostographia*—the standard book of its day on British Grasses. Contemporary with Lawson was John Claudius Loudon (1783–1843), son of a farmer at Gogar, who received his education at Edinburgh and worked at the Leith Walk Nursery—a prolific writer on gardening. He spent most of his life in London, where he published in 1838 his *Arboretum Britannicum.*

These years of rapid development in matters botanical and horticultural in the Edinburgh of the early nineteenth century—both within the University and in the practical business side of horticulture—did not affect only those who were professionally interested in the subject. The intellectual atmosphere of the Edinburgh of that time—both literary and scientific—was of such a noteworthy character as to justify the period being regarded as the most remarkable in the development of the City. On the side of Science some evidence of the fervour of the time is shown by the institution of various scientific societies, some of which still flourish, while others have fallen by the way or been incorporated with more vigorous neighbours. Many of these dealt more or less directly with botanical science. As landmarks in the scientific progress of the preceding century may be noted the institution of various societies. The Honourable the Society of Improvers in the Knowledge of Agriculture in Scotland was founded by John Cockburn of Ormiston in 1723. As a result of the operations of this Society there were established the Board of Trustees for Manufactures and the Board of Fisheries—both in 1727. The Society was broken up by the disturbances of 1745. Other societies are: the Royal Medical Society (1737), the Royal Physical Society (1771), the Royal Society of Edinburgh (1783), the Highland and Agricultural Society of Scotland (1784).

Subsequently the tendency was to produce institutions and societies confined to one branch of science only. As regards botany and the allied sciences this corresponded with the institution of the Wernerian Society (1808); the Botanical Society of Edinburgh (1836); and the Edinburgh Field Naturalists' Society (1869).

One of the most interesting of these associations of kindred spirits was the "Oregon Association," founded for the purpose of sending to N.W. and W. America a botanical explorer to procure seeds and plants for introduction into Europe. John Jeffrey, one of the employees of the Royal Botanic Garden, was selected for the task, and went out in 1851. The results of his work were not so great as had been anticipated, but through this association some interesting conifers and other plants were first brought to Europe. A subsequent association of a similar character sent out Dr Robert Brown to British Columbia in 1865.

The records of the earlier societies bear testimony to much pioneer work in botany as well as in horticulture and agriculture. John Cockburn of Ormiston (d. 1758) was one of the most eminent of Scottish agriculturists, a member of the last Scottish Parliament, and first member for East Lothian in the Parliament of Great Britain. He introduced the cultivation of turnips, rape and clover into Scotland. His *Letters to his Gardener* (1727–44) were published in 1904 by the Scottish History Society.

A contemporary of Cockburn was James Justice (d. 1763), one of the principal Clerks of Session. He had the finest garden in Scotland, at Crichton, near Edinburgh, the only pine-stove, and the largest collection of Auriculas in Europe. He published the *Scots Gardeners' Director* in 1753. For thirty years he kept his garden, but spent so much on it that he had to sell the property. Another Edinburgh horticulturist and agriculturist of the period was Henry Home, Lord Kames, who had extensive gardens at Kames and at Blair Drummond. After their time comes Sir John Sinclair (1744–1835). Educated at the High School and University of Edinburgh, he founded the Board of Agriculture in 1793 and wrote widely on agriculture and kindred topics.

The period of the foundation of the more restricted scientific societies produced many botanists and horticulturists of note.

George Arnott Walker-Arnott, born in Edinburgh in

1799. He co-operated with Hooker in the *Botany of Beechey's Voyage* and in a *British Flora* well known to generations of students. He also co-operated with Wight in papers dealing with Indian Botany. He was appointed Professor of Botany in Glasgow in 1845. Dr Robert Kaye Greville (1794–1866) came for study to Edinburgh at the age of twenty-two. His publications included a *Scottish Cryptogamic Flora, Flora Edinensis, Algæ Britannicæ*, and many papers on the Cryptogams. Sir Robert Christison, Professor of Materia Medica in the University of Edinburgh, 1832–77, wrote numerous papers on the measurement of the growth of timber. Dr Patrick Neill (1776–1851), Secretary of the Wernerian Society, one of the founders and for forty years Secretary of the Caledonian Horticultural Society, was well known as a Pteridologist. Hugh Francis Clarke Cleghorn (1820–95), medical graduate of Edinburgh, spent most of his life in the service of the East India Company. At the Edinburgh meeting of the British Association in 1850 he had a Committee appointed to draw up a return on the probable effects from an economic and physical point of view of the destruction of tropical forests. Cleghorn, as convener, drew up this report, and it was this which induced the East India Company to inaugurate a Forest Department in Madras and subsequently all over India. Cleghorn became Inspector-General of Forests in India in 1867 and is considered "the father of scientific forestry in India." John Thomas Irvine Boswell (1822–88), afterwards Boswell-Syme, born and educated in Edinburgh, a keen student of the native flora. Boswell-Syme's botanical reputation mainly rests on the work he did on the third edition of *English Botany*, which was begun in 1863. Isaac Anderson Henry, a prominent horticulturist and hybridiser. Francis Buchanan White, graduate in medicine at Edinburgh, and one of the originators of the Cryptogamic Society of Scotland. His botanical work included a flora of Perthshire and a revision of the British Willows. George

William Traill (1836–97), the most prominent of Scottish marine algologists.

The influence of Edinburgh in botany cannot be measured only by the work of those who spent their scientific life within or near the city. With the Medical School and the various societies can be associated a long list of eminent scientists who had a more or less intimate connection with Edinburgh. In many instances, perhaps in most, these were medical men, and it is fair to conclude that those who subsequently distinguished themselves in botanical research and exploration were no doubt influenced in their earlier years by the training they received as students in Edinburgh. It is here that the effect of the botanical teaching of Graham and John Hutton Balfour is manifested. Apart from lecture hall and laboratory, these teachers made prolonged excursions into the highlands and lowlands of Scotland in company with those students who were specially interested in the biological sciences. Sometimes excursions were made farther afield, to Ireland, Switzerland and other parts of the Continent. The contribution of these teachers to botanical research is not to be gauged alone by their written papers, but in the stream of medical graduates who, in addition to their own special work, did so much to further botanical exploration in foreign fields. It is not possible to give more in this brief outline than a note of some of the more eminent workers. While claiming certain of these as the product of the Edinburgh school, it is recognised in many cases that their work was done in distant fields. But the great majority kept in touch with their university and the societies of which they continued to be members. In the publications of these societies they frequently recorded their observations and discoveries. Dried plants of many an historic exploration were gifted to their Alma Mater and are now among the treasures of the extensive herbarium situated in the Royal Botanic Garden.

It is difficult to exaggerate the influence exercised on the medical graduates of the day by the enthusiastic labours of these early teachers. To quote but one instance taken from the records of 1834 on the occasion of a botanical excursion to Clova. In a list of twenty-two students who accompanied Professor Graham on that excursion appear the names of John Hutton Balfour, Joseph Dalton Hooker, Giles Munby, Richard Parnell, George Charles Wallich, Hewett Cottrell Watson, Robert Wight—men who have done sterling service to the biological sciences.

It is not easy to refrain from including a few more names associated with that period, as they illustrate so well the far-reaching influence of the biological teaching of the time.

James Edward Tierney Aitchison (M.D. Edin., 1856), Surgeon-General in the Indian Medical Service. He collected extensively in India, was naturalist on the Afghan Delimitation Commission, and wrote several papers on the Asiatic botany, especially on economic products. Thomas Anderson, born in Edinburgh, where he graduated M.D., 1853. Appointed to the Indian Medical Service, he became Director of Calcutta Botanic Garden and took an active part in the introduction of medicinal plants into India, especially Cinchona and Ipecacuanha. His systematic papers deal chiefly with Acanthaceæ. Robert Brown (1773–1858), student of medicine at Edinburgh, esteemed by Humboldt "botanicorum facile princeps." James Bruce, African explorer. James W. Cathcart, member of the Bengal Civil Service, collected extensively in the East Himalaya. Many of the new plants discovered by him were exquisitely figured by native artists under his direction. John George Champion, born in Edinburgh, 1815. He made botanical explorations in Ceylon and Hong-Kong. Nicoll Alexander Dalzell, M.A. Edin., 1837, became Conservator of Forests in Bombay and co-operated with Alexander Gibson (M.D. Edin., 1853) in a *Flora of Bombay* (1861). Hugh Falconer, M.D. Edin., 1829, Superintendent of Saharunpur Botanic Garden and later of the Calcutta

Botanic Garden. He aided the introduction of tea and cinchona to various parts of India and was, in addition to being a botanist, an eminent geologist and palæontologist. Henry Ogg Forbes explored extensively in Malaya and the islands of the Indian Ocean. Robert Fortune (1813–80) worked for some years at the Royal Botanic Garden, Edinburgh, and by his expeditions to China made on behalf of the Royal Horticultural Society introduced many interesting trees and herbs to European horticulture. Francis Buchanan Hamilton, M.D. Edin., 1783, Superintendent of Calcutta Botanic Garden. He wrote much on Indian botany. Sir James Hector, M.D. Edin., 1856, did much geological and botanical work in the Canadian North-West and in New Zealand. Sir Joseph Dalton Hooker was closely associated with Edinburgh. He lectured on behalf of Professor Graham in 1845 just before the latter's death. Sir William Jackson Hooker, one of the founders in 1808 of the Wernerian Society in Edinburgh. William Jameson became Professor of Chemistry and Botany at the University of Quito. He wrote on the flora of South America and made many valuable collections. Gilbert M'Nab, born at Edinburgh, 1815 (M.D. Edin., 1836), son of William M'Nab, Head Gardener of the Royal Botanic Garden, collected in the West Indies and co-operated with Dr M'Fadyen in his *Flora of Jamaica.* William Ramsay M'Nab (1844–89), son of James M'Nab, Curator of the Royal Botanic Garden, became Professor of Botany in 1873 at College of Science, Dublin. David Moore, born at Edinburgh, 1807, worked at the Comely Bank Nurseries and became afterwards Director of the Botanic Garden at Glasnevin, Dublin. Wrote extensively on Irish botany. Mungo Park, student of the University, 1789–91, African explorer. Richard Parnell, an original member of the Botanical Society of Edinburgh, was a prominent agrostologist and ichthyologist. Sir John Richardson, M.D. Edin., 1816, took part as naturalist in Franklin's first Arctic expedition and in two subsequent expeditions to the Arctic. William Roxburgh (1751–1815), M.D. Edin., became Superintendent of the Calcutta Botanic Garden and published many important works on Asiatic botany. John Scott, foreman in Propagating Department of the Royal Botanic Garden for seven years, took an active part in the management of the Calcutta Botanic Garden under Dr Thomas Anderson. He was the friend and correspondent of Charles Darwin. Sir James Edward Smith studied along with Francis Buchanan Hamilton under Professor Hope. He founded the Linnean Society in 1788. Richard Spruce (1817–93) was a member of the Botanical Society of Edinburgh, and in their publications appeared his *Hepaticæ Amazonicæ et Andinæ.* John Lindsay Stewart, M.D. Edin., 1856, Conservator of Forests in the Punjab, published numerous papers dealing with Indian botany and Indian forestry. H. C. Watson, medical student at Edinburgh, author of *Topographical Botany.* He was closely associated with Professors Graham and Hutton Balfour and Dr Greville in many excursions throughout Scotland. Dr Robert Wight, M.D. Edin., 1818, published many important works on the flora of Southern India.

Consideration of these few names culled from a long list of botanical workers and explorers shows how potent was the influence of early training in the Medical School and horticultural institutions.

The tendency of the medical graduate of that day in Edinburgh to the biological sciences led to a long line of *naturalists.* As the Edinburgh of last century had a pre-eminence in this country as a centre for medical teaching, and as medical men were then first choice for attachment to scientific expeditions, it followed that many pioneers in the exploration of the new countries opened to scientific investigation in the nineteenth century owed to their Alma Mater no small proportion of their success in the sciences adorned by their labours. Their mature work is an index of the "mettle of their pasture."

W. W. S.

FORESTRY

The level attained by the science of Forestry in any country largely depends on the extent of its woods and the proportion of those woods belonging to the State. The woods of the United Kingdom, which extend to little more than three million acres, are, whether compared with total area or population, very much smaller than those of other countries, and only 3 per cent. has hitherto been under State management. The science of Forestry has, however, advanced further in this country than its limited scope would lead one to expect. This result must be attributed to (1) the excellence of our soil and climate for tree-growing; (2) the enterprise of private planters and their readiness to experiment with new trees and new methods; (3) the sound practical knowledge traditional among British working foresters; (4) the efforts of the universities and other teaching centres, which have made far more ample provision for forestry education than the limited number of students had any right to expect, and have been singularly fortunate in the devotion and inspiring enthusiasm of their lecturers; (5) the training in this country of foresters for the Indian and Colonial Services, and return of retired officers from these services with experience of forestry administration on a larger scale.

Edinburgh has for a hundred years been the pioneer in the movement for the development of British forestry. The Highland and Agricultural Society, almost from its inception, devoted space in its *Transactions* to this subject. An article printed in 1820 advances the very arguments which a hundred years later have induced the Government to adopt a definite forest policy. Premiums were offered by the Society to private planters, and many of the finest woods felled in Scotland during the war had earned these premiums. The Oregon Association, which about 1850 imported and distributed the seed of the Western American conifers discovered by Menzies and Douglas, placed Scotland in this respect in advance of other European countries. The nursery garden of Peter Lawson played an important part in the same work. His catalogue of 1847–48 offers for sale nearly three hundred species and varieties of conifers, including nearly all those now in cultivation, with the exception of the recent introductions from China, to which W. Forrest, himself an Edinburgh man, has made such important contributions. The Royal Scottish Arboricultural Society, founded in 1854, has its home in Edinburgh. Its published *Transactions*, excursions, and meetings, provide the principal focus of foresters in the United Kingdom. The Forestry Section in the Edinburgh International Exhibition of 1884 was a landmark in the history of British Forestry.

The University, the East of Scotland Agricultural College, and the Royal Botanic Gardens have during the last thirty years each taken an important part in Forestry education. Dr W. Somerville, now Professor of Rural Economy at Oxford, came to Edinburgh in 1889 as first Lecturer on Forestry at the University. His influence extended far beyond his classes, and is still felt in the excursions which he initiated of Scots foresters to the forests of foreign countries. Somerville was succeeded in 1890 by Lieut.-Col. F. Bailey of the Indian Forest Service, who edited the *R.S.A.S. Transactions*, and made and published the first regular working plans for private woodlands in Scotland. Under his auspices a degree in Forestry was established. Dr A. W. Borthwick, now Technical Adviser to the Forestry Commission in Scotland, and Editor of the *R.S.A.S. Transactions*, lectured for many years at the University and Agricultural College, and, apart from his important teaching and research work, became and still remains the personal ally and adviser of private foresters in every part of Scotland. E. P. Stebbing, also of the Indian Forest Service, succeeded Bailey as Lecturer in 1910, and now holds the Chair of Forestry in Edinburgh, recently established with the assistance of the Development Commission. Excellent lecture rooms and museums have been built, and in co-operation with the War Office demonstration nursery and woodland area have been secured. Edinburgh has also been recognised as a centre for the training of Indian Forest probationers. J. Lyford Pike, Lecturer in Forestry, has, for the first time in this country, drawn attention in his lectures to Forest Transport and Machinery, a branch of forestry in which British foresters and timber merchants are peculiarly backward. Space forbids more than passing allusion to the distinguished Edinburgh experts in allied sciences who have taken part in the training of forestry students, and whose original work has helped to build up the science of British forestry. As examples, may be cited the researches of Dr Buchan and others in forest meteorology, Dr Stewart MacDougall's studies of insect pests, and the timber tests recently carried out by Professor Hudson Beare. Special mention must be made of the courses of theoretical and practical forestry provided by Sir Isaac Bayley Balfour at the Royal Botanic Gardens, where many of the most successful British foresters have been trained, many new trees raised, and many scientific problems of silviculture solved. The Arboretum attached to the Gardens was purchased by the Government for the purpose of forestry education.

In view of the experience of the war, and the inroads made into the national reserves of standing timber during the last seven years, the Government has now adopted a definite forest policy which includes the further development of forest education and research. Since the number of students to be trained is not sufficient to warrant the perfecting of each of the numerous centres round which forestry teaching has in this country crystallised, the advanced instruction will take the form of a post-graduate course at a single centre. The University of Edinburgh will continue to confer degrees in Forestry as heretofore, and those of her graduates who desire to carry their training a stage further will proceed to this course. No attempt will be made to concentrate research at a single centre, but problems as they arise will be entrusted to the men of science and schools best qualified for their solution.

J. M. S.-M.

VIII

AGRICULTURE

THE district of the Lothians, of which Edinburgh is the centre, has from early times been accounted one of the most fertile and best farmed in Scotland. Scotland, as a whole, however, clung long to ancient and inefficient methods of farming, and it was not until well after the Union of 1707 that she began to make any noteworthy contribution to agricultural science.

The earliest Scottish work on the subject, Donaldson's *Husbandry Anatomised*, was published in Edinburgh in 1697, but can hardly be said to have added anything considerable to the then existing knowledge. An anonymous pamphlet called *The Countrey Man's Rudiments or an Advice to the Farmers of East Lothian* (Edinburgh, 1699) is interesting for the light it throws on contemporary farming methods; but most of the things recommended, such, for example, as fallowing, liming, and the conservation of farmyard manure, were already part of ordinary farm practice in the more advanced districts of England. Macintosh's well-known *Essay on the Ways and Means for Inclosing, Fallowing, Planting, etc., Scotland* (Edinburgh, 1729), consists, for the most part, in an attempt to persuade Scottish landowners and farmers to adopt English methods; and he recommends, among other things, the bringing north of a battalion of 640 skilled English labourers who were to instruct his countrymen in the arts of husbandry. Nearly all the early improvers were men of the landlord class who had travelled in England, and their improvements consisted mainly in attempts, sometimes rather slavish and undiscerning, to imitate the practices of the South.

Progress in Scottish agriculture was concurrent with the general economic and intellectual development of the country, and was astonishingly rapid. No widespread or general improvement took place till after the '45, yet by 1800 a complete revolution had been effected in the Lothians, and in the remoter districts rapid progress was being made. It is a sufficient commentary on the relative progress of Scottish and English agriculture during this period to mention that, less than a century after Macintosh wrote, Cobbett was complaining of the multitude of Scotch bailiffs who had overrun England. This vast change for the better was no doubt mainly a result of the advent of internal peace, and of the development in trade that ultimately resulted from the Union; but there was another circumstance that made for rapid progress. The old open-field system, which in England was perhaps the greatest of the obstacles to improvement, was in Scotland dead and forgotten before the era of improvement set in. The Celtic type of field system, with small scattered hamlets, which had prevailed throughout the country, permitted redistribution of the land with a minimum of social disturbance. The result was that enclosure was completed very early. A General Enclosure Act was passed by the Scots Parliament in 1695; but even at that time it seems that most of the land in Scotland was already held in severalty. The "Enclosure" advocated by Macintosh is only fencing, and he makes no mention of intermixed holdings.

Of the many inventions and discoveries that were made during the second half of the eighteenth century at least two, of first-rate importance, can be claimed for the district of Lothians and the Merse. In 1763 James Small, a young Scottish carpenter who had worked in England, set up at Blackadder Mount in Berwickshire as a maker of ploughs. The old Scots plough, which was then in general use, was a heavy and clumsy wooden implement " drawn by a pair of horses, with the addition of four and sometimes of six oxen ; the smallest number was a pair of horses and a pair of oxen, attended by a driver." Small experimented long and patiently with various models, using a spring balance to determine the draught and a mould board of soft wood that automatically recorded the amount of friction on its various parts. In 1780 he went to Carron with patterns of his mould board and cheek plates, and had them cast. The addition of an iron hake, a few years later, completed his series of inventions and produced a plough not unlike some of the most recent types, drawn by a pair of horses and managed by the ploughman alone. Small worked ceaselessly and with a most disinterested spirit to get his plough generally introduced, and he published a full description of it in his *Treatise on Ploughs and Wheeled Carriages* (Edinburgh, 1784). He died in 1793, having reaped but very little financial reward for his work.

The chief credit for the invention of the threshing machine belongs to East Lothian. One of the earliest of many unsuccessful attempts was made by an advocate named Menzies, of that county, in 1740. His machine, which was favourably reported on by the Edinburgh Society of Improvers, consisted of a set of flails kept in motion by a water-wheel. The flails, however, broke so frequently that the machine was useless in practice. In 1773 another thresher was invented by a Mr. Ilderton, a farmer near Alnwick, and later his design was taken up and improved upon by Sir Francis Kinloch of Gilmerton in Midlothian. A large model was sent by him for trial to Andrew Meikle of Houston Mill, East Lothian, whose father had introduced the barley mill and winnower from Holland. The model, when the attempt was made to work it, was "in a few minutes torn to pieces" ; but the incident stimulated Meikle to investigate the problem for himself. Following for some time the earlier principle of the flail, he set up a small machine in East Lothian in 1778, which proved but a partial success. Later he invented the revolving drum, and in 1787 he built at Kilbeggie, in Clackmannan, the first completely successful machine. Brown of Markle, in his admirable *Treatise on Rural Affairs* (Edinburgh, 1811), calculated that the general use of Meikle's machine throughout Britain would then have resulted in a saving of grain and labour amounting to £3,600,000 per annum. Meikle took out a patent for his invention, but seems to have been quite powerless to enforce it, and he reaped very little immediate reward from it. In 1810, however, a generous public subscription provided for his old age.

In more recent times, and in a different department, the work of Patrick Shireff as a plant-breeder calls for comment. During his tenancy of Mungoswells, East Lothian, and especially during the period 1819 to 1833, he produced, by the method of pure-line selection, a number of valuable varieties of wheat and oats. He resumed this work, and began hybridisation as well, at Haddington in 1856, and added several more varieties to commerce. A perusal of his book on the *Improvement of Cereals* (Edinburgh, 1873) cannot fail to convince the reader that Shireff was working on very sound lines. Two of his oats, the Hopetown and the Early Fellow, are still grown in certain districts of Scotland.

Of many societies for the improvement of agriculture that have existed in Edinburgh the earliest was the "Society of Improvers," formed in 1723. Its secretary and moving spirit was Maxwell of Arkland, who published the *Select Society Proceedings* in 1743. Maxwell, like many another pioneer improver, ruined himself financially by his experiments, and for some time "Lady Arkland" was reduced to keep a small shop in the High Street. The Society did not survive the '45; but Maxwell lived to deliver two courses of lectures on agriculture, and to publish in 1757 his *Practical Husbandman.*

The Highland Society, which later changed to the Highland and Agricultural Society of Scotland, was established in Edinburgh in 1784. It was the first of the national Agricultural Societies, and has had an eminently successful and useful career. Its activities have included the promotion of agricultural legislation, the collection of statistics, the offer of premiums for essays and for inventions, the conduct of experiments, the trial of new implements, the holding of shows, and many others. In 1842 there was formed a society called the "Agricultural Chemistry Association of Scotland," with Professor Johnston of Durham as official chemist. A number of very valuable investigations were carried out; in 1847 the work was taken over by the "Highland," and has been continued till the present time.

The past few years have been notable for the formation of the "Scottish Society for Research in Plant Breeding" and the "Animal Diseases Research Association." A plant-breeding station was established at East Craigs, Corstorphine, in 1920. A Department of Research in Animal Breeding was established during the same year, controlled by a joint committee of the University and the College of Agriculture, and financed by the Development Commission, the Scottish Board of Agriculture and the University.

The Chair of Agriculture in the University of Edinburgh was founded under an endowment by Sir William Pulteney in 1790. It appears to have been the earliest in any country. The first professor was Dr Andrew Coventry, who has left some interesting *Remarks on Live Stock* (Edinburgh, 1806). Thomas Bates (of Shorthorn fame) was one of his students. David Low, the second incumbent (1831–54) was the distinguished author of *The Breeds of Domesticated Animals* (1842) and of the *Elements of Practical Agriculture*. The Low Collection of a hundred paintings of farm animals, many of which were reproduced in the former of his two books, is still preserved in the University Department of Agriculture.

Low was succeeded by John Wilson (1854–85), who wrote a work on *Farm Crops* (1859) that is outstanding among books on the subject. Prof. Wallace, who now occupies the Chair, has returned to the Low tradition, his chief work being the *Farm Live Stock of Great Britain*. The Steven Lectureship in Agricultural Entomology was established in 1890, with Dr Fream as the first lecturer. This has now grown into a Department of Agricultural and Forest Entomology which, especially since it obtained adequate equipment in 1914, has turned out a considerable volume of research work.

In order to meet the growing needs of Agricultural Education the Edinburgh and East of Scotland College was established in 1901. The College works in close co-operation with the University and provides the teaching in Agricultural Chemistry, Agricultural Botany, Agricultural Bacteriology and Veterinary Science. It is one of the Central Institutions set up by the Education (Scotland) Act, 1918, and it is financed by grants from the Board of Agriculture for Scotland. In addition to the work carried out in the Central Institution, the College has conducted a large amount of field experimental work in the East of Scotland, and forms a useful link between the University Agricultural Department and the practical farmer.

J. A. S. W.

IX

GEOGRAPHY

IT will be appropriate to begin by giving a list of explorers and geographical surveyors connected with Edinburgh. The two first scientific explorers of Africa, James Bruce (1730–94), who between 1768–73 travelled from Massaua to the sources of the Blue Nile, and then by Sennar and the Nubian Desert to Egypt, and Mungo Park (1771–1806), the celebrated Niger explorer, studied at Edinburgh University, the latter graduating in medicine. George Bogle (1746–81), who was the first to cross the Upper Tsanpu, or Upper Brahmaputra, and formed a strong personal friendship with the Lama of Tibet in 1774–75, was also a student at Edinburgh University. John Hunter, who sailed with Captain Arthur Phillip in 1787 to found a penal settlement on the east coast of Australia, and did service to geography by carrying out surveys of Broken Bay and other parts of New South Wales, and was afterwards Governor of New South Wales from 1795–1800, may also be claimed as an Edinburgh man, for though not born in the Edinburgh of his day he was a native of Leith, which is now included within the city. It may here be mentioned that Robert Brown, the botanist (1773–1858) attached as naturalist to the Flinders expedition to Australia, which set out in 1801, was a student of Edinburgh University. Francis Buchanan, afterwards Hamilton (1762–1829), who made extensive travels and investigations in the south of India and in Nepal in the early part of last century, was an Edinburgh graduate. Dr Oudney (1790–1824), a native as well as a medical graduate of Edinburgh, early turned his thoughts to African discovery and, when appointed Consul to Bornu, organised an expedition to Fezzan and Kuka on Lake Chad, an expedition on which he took with him Hugh Clapperton, another Scotsman, though not an Edinburgh man, who afterwards distinguished himself in African exploration, and whom he first met at Edinburgh. Oudney died in the winter of 1824 on a journey to West Bornu, and some of the results of his explorations were afterwards published by Denham. Alexander Gordon Laing (1793–1826), who was dispatched by Sir Chas. MacCarthy into the Gambian and Mandingo countries, and subsequently crossed the Sahara from Tripoli to Timbuktu, whence his last letter, 21st September 1826, is dated, was also a native of Edinburgh. Sir Andrew Smith (1797–1872), a native of Roxburghshire, who graduated as M.D. at Edinburgh University in 1819, in a South African expedition made in 1834–35, reached the Tropic of Capricorn and brought back the first certain intelligence as to the Upper Limpopo. John M'Douall Stuart (1815–56), who is reckoned the most celebrated of Australian explorers, a native of Dysart in Fife, was educated in Edinburgh. John Rae (1813–93), the Arctic explorer, who proved King William Land to be an island and was the first to obtain authentic news of the fate of Sir John Franklin, an Orkney man by birth, was also educated at Edinburgh. Dr Robert Brown (1842–95), who in 1864 led an expedition to, and mapped a portion of, the interior of Vancouver Island, and was afterwards joint author with Sir Lambert Playfair of the *Bibliography of Morocco*, issued by the Royal Geographical Society, a Caithness man by birth, was an Edinburgh graduate. Sir Jas. Hector, the discoverer of the Kicking Horse Pass, by which the first line of the Canadian Pacific Railway crossed the Rocky Mountains, afterwards the Director of the Geological Survey of New Zealand, was a native of Edinburgh. Joseph Thomson (1858–95), a native of Thornhill, Dumfriesshire, received his training in geology and other branches of natural science at Edinburgh University. He accompanied Alexander Keith Johnston, himself an Edinburgh man, on the Royal Geographical Society's expedition to East Central Africa and, on the death of his leader, assumed command and brought the expedition to a successful conclusion. He afterwards travelled in many parts of the same continent, leaving behind him wherever he went a favourable impression of the British name. H. B. Cotterill, who in 1877 made a journey from Lake Nyasa to Ugogo, is a son of the late Bishop Cotterill of Edinburgh. The achievements of Dr W. S. Bruce as an Arctic and Antarctic explorer are more appropriately commemorated elsewhere in this *Handbook*. So also is the work of Dr H. R. Mill and the late Prof. Herbertson; but it may be mentioned here that the work of Dr Mill includes a survey of the lakes of the English Lake District, made for the Royal Geographical Society, the results of which are published in vol. iv of the *Geographical Journal* (1894). It may also be mentioned here that the survey of the Scottish lakes, made at the instance of the Royal Geographical and Scottish Geographical Societies, was carried out under the direction of the late Sir John Murray, who spent his last years at Edinburgh. Sir George Adam Smith, D.D., LL.D., now Principal of Aberdeen University, was educated at the Royal High School, the University, and the New College (Theological), Edinburgh. His travels in Egypt, Syria and Palestine are important geographically, yielding results which are embodied in his *Historical Geography of the Holy Land* (1894; 7th ed., 1901), his *Jerusalem: its History, Topography, and Economics* (1908), and, with Dr. Bartholomew, *Atlas of the Historical Geography of the Holy Land* (1914).

To come now to arm-chair geographers connected with Edinburgh, mention may first be made of George Buchanan (1506–82), who spent the last years of his life at Edinburgh, and there wrote his *Historia Rerum*

Scoticarum, the first book of which gives an interesting account of Scotland as it was in his day, containing sundry notes on the influence of geographical conditions upon the people after the manner of Strabo, but with this notable difference that, whereas Strabo delights in noting the natural wealth of regions, Buchanan is much more disposed to indite the praise of poverty or, at most, such natural wealth as excludes all possibility of luxury. Of one small island he says: "Here alone in the universe, I imagine, are to be found a people who know no want, among whom every necessary of life abounds even to satiety. Unacquainted alike with luxury and avarice, they find in their ignorance of vice that innocence and tranquillity of mind which others laboriously search for in the discipline and the precepts of wisdom. Nor does anything seem wanting to consummate their supreme felicity, but that they should understand their own good fortune" (Aikman's translation, vol. i, p. 55). This island is the island of Rona, less than a mile in length, situated about sixty miles, he tells us, actually only forty-five, to the north-east of Lewis. Alexander Dalrymple (1737–1808), Hydrographer to the Admiralty, author of a *Historical Collection of South Sea Voyages* (two vols., 4to, 1770–71), was a native of Midlothian. James Macqueen (1772–1870), one of the most keen-sighted of arm-chair geographers, who succeeded in proving the true course of the Niger by piecing together information derived from publications as well as the oral communications of negroes with whom he became acquainted in the West Indies, published at Edinburgh the work in which he set forth his views, *Geographical and Commercial View of Northern Central Africa*; but this seems the only ground on which he can be connected with the city. Colonel Yule (1820–89), the learned author of *Cathay and the Way Thither* and *The Book of Ser Marco Polo*, was a native of Inveresk, but was educated at Edinburgh. Dr J. Watson M'Crindle (1825–1913), graduated with distinction at Edinburgh in 1854, and after returning from

India settled in Edinburgh, and there brought out a series of works, annotating classical writers dealing with the geography of India and the Indian Ocean.

It is, however, by its cartographical establishments that Edinburgh has acquired most fame in connection with geography. The principal firms have arisen through the association of Edinburgh with printing and engraving.

Of the two great firms belonging to Edinburgh the older is that of John Bartholomew & Son, which was established in 1820 by John Bartholomew, geographical engraver, who was succeeded by his son, John Bartholomew, F.R.G.S., in 1861, his grandson, John George Bartholomew, LL.D., in 1888, and by his great grandson, Capt. John Bartholomew, M.C., in 1920. The firm had previously, however, in 1919, become a private limited company, of which Capt. Bartholomew is the present Managing Director. It was under the direction of the late Dr J. G. Bartholomew, to whom the Royal Geographical Society awarded the Victoria Research Medal in 1905, that this firm acquired its high reputation. It was he who first introduced the method of layering in the construction of topographical maps, particularly in his half-inch atlases of Scotland, and of England and Wales. By the publication of the *Atlas of Meteorology* (1899), and that of *Zoogeography* (1911), designed to form parts of a vast atlas of physical geography, the firm placed itself in the first rank in that branch of science. The firm is at present engaged in the publication of *The Times Survey Atlas of the World.* Its first printing works were situated in Carrubbers Close, High Street. Later it removed first to Chambers Street, then to occupy part of the building belonging to the publishing firm of Nelson in the Dalkeith Road. Its present premises in Duncan Street were opened in 1911.

The second of the firms referred to is that of W. & A. K. Johnston, in which it may be mentioned the celebrated geographer, Dr Alexander Petermann, the founder of *Petermanns Mitteilungen*, worked for a time.

This firm was founded by William, afterwards Sir William Johnston, at 6 Hill Square in 1825, but first took to map-making after the founder was joined by his brother, Alexander Keith Johnston. This member of the firm having in 1830 gone with some friends on a walking tour in the West Highlands, and found the maps very incorrect, turned his attention for the rest of his life to geography, his services to which were recognised in 1865 by the award of the degree of LL.D. by Edinburgh University, and in 1871 by the award of the Patron's Medal of the Royal Geographical Society. The firm removed from Hill Square to 160 High Street in the year after its foundation, and its headquarters remained there till 1878–79, when the establishment was moved to the large premises known as the Edina Works in Easter Road. The most important works produced by this firm are the *National Atlas* (1843), the *Physical Atlas* (1848), and the *Royal Atlas*, which was first published in 1861, and has been brought up to date in repeated editions. A smaller atlas is published under the title of the *Handy Royal Atlas*, a new edition of which, taking account of the recent changes in the map of the world, has just appeared.

A third Edinburgh firm, that of Messrs Gall & Inglis, Bernard Terrace, is known to all cyclists and motorists for their useful Contour Road Books with their admirable graphical system of representing road gradients. Here also may be mentioned a map projection invented by the Rev. James Gall, which has been largely used by Edinburgh firms. An account of it is given in the first and sixth volumes of the *Scottish Geographical Magazine*. Its aim is to reduce the exaggeration in magnitude of polar regions on Mercator's Projection, by conceiving the cylinder on which the map is projected, not as tangent to the equator, but as cutting the earth in the parallels of 45° N. and S.

The foundation of the Scottish, now the Royal

Scottish Geographical Society, may also be mentioned as one of the most important means by which Edinburgh has promoted the progress of geography. The Society was founded at the close of 1884 at Edinburgh by a number of enthusiastic geographers, among whom J. G. Bartholomew, already mentioned, was conspicuous, and though it now has centres at Glasgow, Aberdeen, and Dundee, Edinburgh has always been its headquarters, is the seat of the valuable geographical library which the Society has collected, and is the place of publication of the *Scottish Geographical Magazine,* which has appeared uninterruptedly since the beginning of 1885, although the influence of the war has been unfortunately seen, first in the reduction of extent, and afterwards in its conversion from a monthly into a quarterly. Among the more important scientific articles which have appeared in its pages, many of them illustrated with original maps, may be mentioned those on *The Geographical Evolution of Europe* and *The Evolution of Climate* by the late Prof. James Geikie, in volumes ii and vi respectively; those by Sir John Murray, on *The Drainage Areas of the Continents and their Relation to Oceanic Deposits* (vol. ii), on *The Total Annual Rainfall in the Land of the Globe and the Relation of Rainfall to the Annual Discharge of Rivers* (vol. iii), on *The Height of the Land and the Depth of the Ocean* (vol. iv), on *The Effects of Wind on the Distribution of Temperature on the Sea and Fresh-Water Lochs at the West of Scotland* (vol. iv); those on *The Mapping of the World,* by J. G. Bartholomew (vols. vi and vii); *A Review of Swedish Hydrographical Research in the Baltic and North Seas,* by Otto Pettersson (vol. x); those on *The Botanical Survey of Scotland, Edinburgh and North Perthshire Districts,* by Robert Smith, in vol. xvi; *Forfar and Fifeshire Districts,* by William G. Smith, in vols. xx and xxi; that on *The History of the Geography of Scotland,* by Sir Arch. Geikie (vol. xxii), and that on *The Shifting of the Climatic Belts,* by Prof. Penck (vol. xxx); those giving some results of the Scottish National

Antarctic Expedition (vol. xxi), by Dr. Bruce and others. Specially valuable issues of the *Magazine* are the Antarctic number (Oct., 1898, vol. xix) and the profusely illustrated Edinburgh and Glasgow numbers (vols. xxxv, 1, 1919, and xxxvii, 2, 1921, respectively).

Since 1902 the *Scottish Geographical Magazine* has been edited by Dr Marion I. Newbigin, who has contributed a number of articles dealing with the Problems of the Near East. Articles on various aspects of Commercial Geography have been contributed by the present writer; and geographical essays by his students have also found a place in the *Magazine*.

Among the other activities of the Royal Geographical Society may be mentioned the foundation of the Committee for the National Collection of Old Maps of Scotland, which was initiated by the late Dr J. G. Bartholomew and Mr Harry Inglis.

Recognition should also be given to the important geographical work done under the influence of Prof. Geddes in the Outlook Tower, near the head of the Lawnmarket, where the exhibition illustrating the surveys of Edinburgh and the Edinburgh district is of exceptional interest.

Finally it may be mentioned that Edinburgh University was the first of the Scottish universities to establish a lectureship in Geography (1908).

G. G. C.

X

ANTHROPOLOGY

Archaeology—Physical Anthropology

ARCHAEOLOGY

THE most interesting feature of the Archæological work carried on in Scotland during the period which has elapsed since the British Association visited Edinburgh in 1892, is the extent to which systematic excavation has been employed for the investigation of ancient sites, and the remarkable discoveries which have been made by this means. Looking back, it seems to us that time was when antiquaries made little effort to obtain relics of the past, but were content to study such things as were accidentally found by men who were ploughing, or digging drains or foundations. Even then, no doubt, there were enthusiasts who devoted some of their spare time to making excavations in cairns, burial mounds and small hill forts, in the hope of throwing some light on the origin and purpose of these mysterious structures. The Ayrshire and Galloway Archæological Association had opened up crannogs in the early eighties, and the Glasgow Archæological Society had followed the good example by making sections on the Roman Wall in 1890–3. But it was not till 1895 that work on a large scale was attempted. In that year the Dumfriesshire and Galloway Natural History and Antiquarian Society approached the Society of Antiquaries of Scotland in Edinburgh and asked them to help in exploring the Roman site at Birrens, near Ecclefechan. The latter Society agreed, and allocated a grant of £40 to meet the expenses. The work was begun on May 29, under the direction of Dr James Macdonald, for many years Rector of Kelvinside Academy, and James Barbour, Architect, of Dumfries. The investigation proved to be a much bigger affair than had been anticipated. The area enclosed within the fortifications, nearly 4 acres, had been covered with stone buildings, and its streets were arranged according to the normal plan of a Roman camp. There had been two occupations, for there was clear proof of rebuilding. A notable discovery was thirteen fragments of an inscribed tablet which had been erected by the Second Cohort of Tungrians in 158 A.D. It had borne the name of a hitherto unknown Roman Governor of Britain, but unfortunately the part of the stone on which this had been cut was amissing. The inscription could not be completed until 1903, when a tablet was found in the Tyne, at Newcastle, which supplied the missing name—"Julius Verus." There were also found at Birrens two altars, many fragments of pottery and glass, a number of small articles of iron and bronze, and eleven coins. The actual cost was £268.

The success of this work was a revelation of the results which might be obtained by well-organised excavation on the sites of Roman camps, and the Society of Antiquaries resolved to promote such investigations in future as opportunity might permit.

Ardoch had long been known as "the finest Roman camp in Scotland" on account of the extent and magnitude of its earthworks, and the Society explored it in the following year. It is situated 7 miles north-west of Dunblane, near the line of the Caledonian Railway. The enclosed area is 5 acres in extent, but it was only possible to examine rather less than the half. However, the results so far obtained fairly justified the following conclusions. There had been, at least, two occupations, and the ground had been covered by structures laid out in the usual regular way. A number of buildings had been made of wood, and could only be traced by the rows of holes in which the posts which supported the side-walls had been fixed. The quantity of pottery, glass, etc., which was found was meagre, and the proportion of the finer ware to the coarser vessels was extremely small. One curious discovery was made. Certain low mounds near the centre of the camp had always been known as "the Prætorium." But a little digging showed that these mounds covered the remains of an early fifteenth-century chapel, and that the real prætorium was situated in quite another place. A tradition of this chapel lingers in the district, but no literary reference to it is known, and its situation had been quite forgotten.

In the summer of 1898 a group of camps at Birrenswark Hill, 3 miles north-west of Birrens, was examined, but the results were not very conclusive. Camelon, near Falkirk, and Lyne, near Peebles, were explored during the next two seasons. The remains of stone buildings similar to those at Birrens were found at both places, and Camelon supplied a large quantity of fragments of pottery and glass, and some enamelled fibulæ. At Lyne, on the other hand, such small articles were not numerous.

The next summer, 1901, was devoted to the exploration of Inchtuthil, by desire of Sir Alexander Muir Mackenzie of Delvine, the proprietor. This camp stands on the left bank of the Tay, about 7 miles below Dunkeld. The fortified area is fully 55 acres in extent. It is notable that though there appeared to be no buildings or other indications of a long occupation within the ramparts, a bath-house of a remarkably permanent character, and provided with a double heating apparatus, was almost accidentally discovered about 100 yards outside of them, near their south-eastern corner.

Castlecary and Rough Castle, forts on the Antonine Wall to the west of Falkirk, were excavated in 1902 and 1903. Buildings and small objects of the usual kinds were found, but the most interesting discovery was a series of pits or "lilia" which had been made for the defence of the north front at Rough Castle.

Bar Hill, near Kilsyth, supplied more relics of the Roman garrison, and more information about the Roman campaigns in northern Britain, than any of the other sites which up to that time had been examined. For this most instructive investigation archæologists are under the deepest obligations to Alexander Whitelaw of Gartshore, who took a personal interest in all the work, and carried it on for nearly three years (1902–5) entirely at his own expense. The well of the fort produced an altar, an inscribed tablet, a number of column-shafts, fourteen bases and eleven capitals, and a great many small articles. The description of the finds in this camp occupies eighty pages of the *Proceedings of the Society of Antiquaries of Scotland*, so it is needless to attempt any further reference to them here; but two may just be mentioned as they are rather unusual, namely, a fine wooden wheel and three hundred or four hundred specimens of leather foot-gear. Interesting as the relics were, the most important discovery at Bar Hill was an early fort on which the well-known camp had been superimposed at some later time. The area of the later camp is about 3 acres, and it was surrounded by a rampart similar to the great Wall in construction. While searching for the cause of the subsidence of one of its buildings, the workmen came upon a large ditch, which, when followed up, proved to be part of the defences of a smaller fort about half an acre in size. The early fort had obviously been abandoned for many years before the builders of the later one arrived. As the later one belonged to the Antonine period (about 140 A.D.), the earlier must be connected with Agricola's campaign in 81 A.D. In this excavation Archaeology was "for the first time brought into immediate certain contact with the handiwork of Agricola."

In the spring of 1905, the Society of Antiquaries undertook what they expected to be a brief excavation at Newstead, near Melrose, which had been known for more than fifty years as a Roman site, although no traces of a former occupation were visible on the surface of the ground. The work lasted for five years. And this is not surprising, for the fort was found to have an area of as many as 14 acres, while adjacent to it were three "annexes" and a "great camp." Moreover, all the work was conducted with the utmost patience and thoroughness. A full description of the discoveries may be found in James Curle's book, *A Roman Frontier Post* (1911), but here it must suffice to say that by close study of the alterations in the buildings and earthworks he was able to trace the history of the fort from the time of Agricola, when it was first constructed, till it was finally evacuated under Commodus towards the close of the second century. A new feature of the work was the careful examination of refuse-pits. Very few pits had been found in the excavations hitherto carried out in Scotland, and even these had not been thoroughly investigated. At Newstead 107 were cleared out, and relics were found in very large numbers. Many articles were also found in the ditches and in the exploratory trenches, and altogether over 2300 objects were added to the collection in the National Museum. The most important, unquestionably, were two helmets of iron, one having an iron mask attached to it, also a brass helmet and a brass mask. The masks are in the form of human faces of great beauty. One of the helmets is undecorated, but the other two are very fine specimens of artistic workmanship. Both the masks and the helmets are in a wonderful state of preservation. Such things had never been found in Scotland before, and there are very few specimens in English, or even in European museums. The cost of the Newstead excavations was £2159, of which £309 came from the Society's funds, while £1850 was raised by subscriptions from Fellows and members of the public. The contrast in outlay and in results with Birrens is instructive.

Cappuck, 3 miles east of Jedburgh, was explored by G. H. Stevenson of Oxford and S. N. Miller of Glasgow University, who were aided by a grant from the Carnegie Trustees. This fort, about 1¼ acres in extent, is situated on Dere Street—the Roman route from Corbridge on the Tyne, across the Cheviots, into northern Britain. The excavations were made in the autumn of 1911 and the spring of 1912, and proved that the camp had been originally constructed by some of Agricola's troops. Bemulie, on the Antonine Wall, the report on which has not yet been published, was excavated by the Glasgow Archæological Society in 1913, 1914 and 1915, and was the last of the sites in which an effort was made to ascertain the character of the interior buildings by excavation. Work of a less ambitious kind has, however, been continued in two directions.

(1) The scientific study of the Antonine Wall by the Glasgow Archæological Society in 1890–3 and the subsequent excavation of the forts, has added much to our knowledge of its history. The results obtained up to 1911 will be found set forth in Dr George Macdonald's book, *The Roman Wall in Scotland.* Since then further progress has been made by a series of minor excavations which Dr Macdonald has carried out at intervals with the help of a Research Grant from the Carnegie Trust for the Universities of Scotland. The sites of six forts that were more or less doubtful have been ascertained, and other information of value secured.

(2) In 1914 and 1915 Professor Haverfield and Dr George Macdonald visited the north-east of Scotland and made "flying reconnaissances" at Raedykes, 3 miles north-west of Stonehaven, and at Glenmailen, half-way between Fyvie and Huntly in Aberdeenshire. A few sections were cut in the ramparts and ditches, and a careful study was made of all remaining surface defences. Glenmailen was found to be a Roman encampment, and, so far as is known, it is the farthest point north which

the invading army reached. Raedykes was also found to be Roman, though the laying out of the rampart has, in some places, departed from the normal rectangular form owing to the nature of the ground. The report of this investigation gives a warning against attaching too much importance to the ordinary notions of "Castramentation" as being invariably rectangular, for the supposed rigidity of these principles is "only partially founded on fact."

This research into the Roman occupation extended over twenty years, during which the work was only suspended in the winter months and at a few other times. The success achieved was in great measure due to the reliable and intelligent foremen who had actual supervision of the operations. Dr Thomas Ross, Architect, made the plans of Newstead,—five seasons' work,—Inchtuthil and Lyne, and Mungo Buchanan those of Camelon, Castle Cary and Rough Castle. The preparation of these drawings involved an immense amount of work which was most ungrudgingly given. Newstead is described in a special volume. The reports on the other investigations (except Bemulie) fill more than 800 pages of the *Proceedings of the Society of Antiquaries*, so the reader will not be surprised if the very meagre report for which there is room here appears to omit much which should have been included. A great deal of investigation still remains to be done. For one thing, the site of "Mons Graupius" has not yet been identified! But the future may be regarded with confidence and hope. The later excavations have taught many things about the art of excavating which were unknown to the earlier explorers, and whenever work of this kind is taken up again there is every reason to believe that a further great increase will be made to our knowledge of the Roman occupation.

While the energies of the Society were devoted to the investigation of Roman sites, private enterprise examined many cairns, mounds and other prehistoric remains. But in 1914 the Society decided to explore

Traprain Law, a much larger piece of work than anything of the kind which had as yet been taken in hand, and which would be quite beyond the powers of any private individual. Traprain is a conspicuous hill situated about 1½ miles to the south of East Linton. Traces of human occupation are visible on the upper parts, but, so far as was known, no attempt had ever been made to investigate them. Work was carried on during two summers, and a number of interesting relics were found as well as evidence of four occupations. During the years 1916 and 1917 the operations had to be suspended, but they were resumed in the spring of 1918. On the 10th of May, within a fortnight of the commencement of the work, the foreman brought up a silver bowl on the point of his pick! A most careful search was immediately made, and thus was found "the Treasure of Traprain." This is a remarkable hoard, of about 770 oz. troy of silver plate which had been brought from the Continent and deposited on the hill early in the fifth century. Some of the vessels were Christian, some pagan, and some could not be assigned to either category. All had been ruthlessly crushed and hacked in pieces by people who cared nothing for beauty of design or workmanship. The Treasury authorised a grant of £1000 to meet the cost of repairing the silver so far as practicable, and Messrs Brook & Son have very skilfully executed this delicate task. The exploration of this site has been continued with excellent results, and the work is still going on.

Excavation has also been carried out at several mediæval buildings, and has led to interesting discoveries connected with their history. In 1910–11 the Commissioners of H.M. Works, at the suggestion of the late Lord Guthrie, authorised the making of an effort to trace the original form of the choir of the Abbey Church at Holyrood. The work was done under the supervision of W. T. Oldrieve, F.R.I.B.A., H.M. Principal Architect for Scotland, and the foundations of the choir were traced out. Remains of an early church, which appears to have existed before the Abbey was founded, were also discovered, as well as the foundations of the mediæval Chapter House. In the following year, 1912, a sub-committee of the Royal Commission on the Ancient Monuments of Scotland recommended investigations under the Half-Moon Battery at Edinburgh Castle with the view of tracing earlier buildings adjoining the Palace. The sanction of the Commissioners of Works was obtained, and W. T. Oldrieve again took charge of the work. Extensive remains of the Tower which King David II commenced to build in 1367 were found. It had been a "keep," very similar to the one at Craigmillar Castle, near Edinburgh. During Sir William Drury's siege in 1573 the masonry was badly shattered. Soon after the siege the Regent Morton got possession of the Castle, and he then built the Half-Moon Battery in front of the ruins of the old tower, which was covered up. Excavations were also made in the Nave of Dunfermline Abbey, which solved some historical puzzles. Dr P. Macgregor Chalmers, Architect, on application to the Carnegie Dunfermline Trust, was enabled to carry out this work, and he succeeded in tracing the foundations of two churches. He believes that the smaller one was the ancient church in which Queen Margaret was married (about 1070), and that the larger building on the east was the church which she founded immediately after that event. He also believes that the Norman nave was the work of David I (1124–53). The position of these foundations is now distinctly marked on the floor of the nave.

In this brief sketch it seemed best to deal chiefly with special efforts and new departures, and no room has been left for reference to the ordinary work of the Societies, most interesting though it has been. Particulars of it may be found in their publications. In these are printed careful records of many stone circles, hill forts and other mysterious remains, which will be invaluable to any student who may hereafter attempt to find out the origin and purpose of these structures. In the publications also may be found numerous papers written by acknowledged authorities, which clear up many historical questions.

During the last thirty years there has been a remarkable change of sentiment in Scotland in regard to relics of the past, and the destruction of sixteenth-century houses which disgraced Edinburgh forty years ago would not now be tolerated. Government, also, has taken action for promoting the preservation of ancient buildings. The Ancient Monuments Commission was appointed in 1908 " to make an inventory of the Ancient and Historical Monuments " in Scotland from the earliest times down to the year 1707, and " to specify those which seem most worthy of preservation." The surveys of six counties have been completed, and the work is still being proceeded with.

The " Ancient Monuments Consolidation and Amendment Act, 1913," increases the powers of H.M. Commissioners of Works for the guardianship and protection of Ancient Buildings, and also simplifies procedure. Under its provisions the " Ancient Monuments Board " has been constituted to advise owners and others as to the treatment of old Castles, Churches, Dwelling-Houses and " Monuments." Many important ruins have been placed under the care of the Commissioners, and many more will be entrusted to them as their powers become generally known.

Those who can look back on thirty or forty years of Archaeology in Scotland will realise how much the progress which has been made and the change of sentiment which has taken place are due to the work of Sir Arthur Mitchell and Dr Joseph Anderson. They came upon the scene about 1870, and from that time onwards they constantly insisted that Archaeology was a science, and that relics of the past must be studied by the usual methods of scientific investigation. Between 1871 and 1891 the Fellowship of the Edinburgh Society rose from 351 to 728. By the latter date there were people in every part of Scotland who had come under the influence of these leaders, and who were quite prepared to carry out their ideas practically if opportunity occurred. There was therefore a certain "atmosphere" in the country about the time the Excavations on Roman sites were begun which was favourable to them. These excavations have greatly increased the popular interest in Archaeology, and we may be assured that in the future greater things will be accomplished than any that have hitherto been done.

J. H. C.

Physical Anthropology

Regular and precise study of Physical Anthropology in Edinburgh was initiated and developed by the late Sir William Turner, during his tenure of office as Professor of Anatomy.

It is true that specimens of interest, from the point of view of Physical Anthropology, had been collected and more or less fully described by much earlier observers, and it is certain that the writings of Linnæus, Buffon, Camper, Blumenbach, Soemmering, Pritchard, Lawrence, Morton, Anders Retzius and Desmoulins were well known, were followed with interest as they appeared, and were discussed in scientific circles in Edinburgh, but Robert Knox appears to have been the only man of eminence, before Turner, who devoted any really serious attention to the subject, and his most important contribution to it was not published till 1850—that is, not until after he had left Edinburgh.

The three Monros, Goodsir and Sir John Struthers all collected specimens of anthropological interest, some of which are still present either in the Anatomical Museum of the University or in the Museum of the Royal College of Surgeons, but Turner was by far the most energetic collector, and it is mainly due to his energy, and the interest he stimulated in his students, that the University possesses a collection of over 1600 skulls, many complete skeletons and numerous limb bones of various races, amongst which the two most important groups are perhaps 237 Scotch skulls and 275 Australian skulls.

Some of the specimens were purchased, but the majority were gifts from generous donors, many of whom had been students in the University. They are too numerous to mention individually here, but Dr Ramsay Smith (Head of the Department of Public Health of South Australia) stands out prominently amongst them, for he has presented to the Museum 600 specimens illustrating Australian Anthropology, including 200 Australian skulls.

Turner commenced his earlier investigations upon skulls in 1864, before he was appointed to the Chair of Anatomy. After he became Professor of Anatomy he made reference to points of Physical Anthropology, in a general way, in his course of lectures on Anatomy, and in 1893 he established a class on the subject in the Science Faculty of the University. It was first instituted as a lecture course, but the practical side of it was gradually developed and now forms its most important part.

Most of the skulls in the Anatomical Museum of the University and many of the bones of the extremities, except the Australian specimens, have been described by Turner, either in his *Challenger Reports* or in his accounts of the *Craniology of the People of Scotland* (*Trans. R.S.E.*, xl, 1902, and li, 1915) and the *Craniology of the People of the Empire of India* (*Trans. R.S.E.*, xxxix, 1899, xl, 1900, xlv, 1906–7).

Other researches have been made upon various parts of the material by Professor Arthur Thomson and by Professor David Hepburn when they were demonstrators in the Anatomy Department. The late Professor D. J. Cunningham utilised the material when he occupied the Chair of Anatomy, and, more recently, Dr Quarry Wood has described some of the Australian limb bones, but the greater part of the valuable Australian material given by Dr Ramsay Smith still awaits competent workers.

A. R.

XI

MEDICINE AND SURGERY

Medical School to 1870—Progress of Surgery—Medical School since 1870

MEDICAL SCHOOL TO 1870

IN estimating the scientific progress of medicine in any locality or at any epoch, one would not be justified simply in enumerating the facts discovered or the theories advanced by individuals of a given period or school. Many important advances in the art of healing are applications of discoveries in quite other sciences, or have followed upon changed economic conditions, or are associated with the development of general culture and humanitarianism. In the progress of a medical school, therefore, one has to consider not merely the isolated discoveries of its workers, but its organisation, its teaching influence, and its effect upon the life and thought of mankind. Unlike the physical sciences, medicine can show few immediately complete discoveries. Even the idea of the circulation of the blood, which the popular mind attributes solely to Harvey, was initiated in the works of Galen, and Harvey's admirable demonstration omitted to show how the blood passed from the arteries to the veins. This essential part of the circuit was not demonstrated till after his death by Malpighi and Leeuwenhoek.

In the Edinburgh School of Medicine, if one excepts a few discoveries such as that of "fixed air" by Black, of the diverse functions of the nerve-roots by Bell, of the anæsthetic properties of chloroform by Simpson, of the properties of certain powerful drugs by Christison, and of the importance of antiseptic procedures by Lister, the influence of Edinburgh medicine has been of a steady constructive rather than of a revolutionary type.

Scotland possessed no mediæval School of Medicine, though in the presence of Michael Scot at Salerno and Bernard Gordon at Montpellier the capacity of Scotsmen as teachers was early recognised. Owing probably to the frequency and facility of intercourse between the East of Scotland and France the study of anatomy was early prosecuted in Edinburgh, certainly in the early years of the sixteenth century, and therefore before the renaissance of anatomy that began on the Continent with the publication of Vesalius's *Fabrica* in 1543. It was initiated by the Corporation of Surregianis and Barbouris, which must be regarded as a trade guild rather than a learned body. Some of its members rendered good service in war-time; and no doubt often passed overseas like Maister Peter Lowe of the West Country, who became a Doctor in Surgery of Paris and Surgeon to the King of France, and who, returning to his native country in 1597, founded the Faculty of Physicians and Surgeons in Glasgow. During the seventeenth century anatomy was regularly taught and entrants to the Corporation were regularly examined in this subject; while in 1705 a Professor of Anatomy, Robert Elliot, was appointed in the Town's College at a yearly salary of £15, "as an encouragement to young men to stay at home instead of travelling to foreign universities, which was attended by expenses and perils to youth."

During the seventeenth century Edinburgh had become a place of considerable social, political and literary importance; and though in the early part of the century it boasted no medical school beyond the anatomical instruction given to the barbers and surgeons, it possessed physicians of ability and distinction, who occupied moreover a respected social position.

The general practitioner of the seventeenth and eighteenth centuries in Scotland, as in England, was a Chirurgeon-Apothecary professing to heal wounds and cure diseases, making and selling drugs, operating with instruments often made by blacksmiths and much inferior to the fine steel instruments of the French surgeons. He bound himself for an apprenticeship of three years and received instruction from the master, whom he helped in practice, not being permitted to attend any lectures for the first two years. Probably the majority, unless they lived either in Edinburgh or Glasgow, never attended any lectures, and stood a very perfunctory examination before they were licensed to practise. The Book of Discipline presented to the Scottish Parliament in 1560 had proposed to institute in the University of St. Andrews, alone of the three Scottish Universities, a School of Medicine in which a reader should carry students through a course of five years, but the proposal fell into abeyance. In 1599 James VI gave a charter to the Faculty of Physicians and Surgeons at Glasgow, but this body existed for disciplinary purposes only; and the sole attempt in Scotland at public teaching of medical subjects before the late seventeenth century was that of the Corporation of Surgeons and Barbers in Edinburgh. The Edinburgh physicians had attempted to form a College in 1617, and in 1621 an order for its foundation had actually been granted by James VI, but the project being opposed was dropped for half a century. About 1670, however, the leading physicians of Edinburgh, moved by the desire to reform medicine, set themselves to lay out a physic garden and to obtain a charter for the institution of a College of Physicians. The men chiefly concerned in this movement were Sir Robert Sibbald, Sir Andrew Balfour, Dr Archibald Pitcairne, Sir Thomas Burnet and Sir Archibald Stevenson. As these men virtually began the Edinburgh Medical School, a few words ought to be said regarding each.

It should be remembered that at this period Sydenham was practising in London. Harvey's discovery had been published over forty years previously and was still disputed, though Borelli by his laborious mathematical investigations had developed its principles into the Iatro-mechanical School of Thought. Boyle, Mayow, Willis and kindred spirits of the Royal Society of London were studying various problems of life and disease. Malpighi and Leeuwenhoek were using the earliest microscopes to investigate the structure of the bodily fluids and tissues. Sylvius at Leyden was founding physiological chemistry and introducing the new idea of instruction in the wards of his hospital as a part of medical education.

Sir Robert Sibbald (1641–1722) more than any one else may justly be regarded as the founder of the Edinburgh Medical School. He had gone through a theological course in Edinburgh, and in 1660 proceeded to Leyden to study Medicine. Here he stayed a year and a half studying anatomy and surgery under Van Horne, botany under Vorstius, and the institutions and practice of medicine under the famous Sylvius. He says, "I frequented ane apothecaryes shop and saw the materia medica and the ordinary compositiones made. I studied chemie under a German called Wittichius, and after he went away, under Margravius, brother to him who wrott the naturall history of Brasile. Sometyme I heard the lessons of Van der Linden, who was famous for critical learning." Such was a medical course in the seventeenth century. Sibbald afterwards went for nine months to Paris, where he further studied botany, visited the Hôtel Dieu and the Hospital of the Charity, and then proceeded to Angers, where he obtained his diploma of Doctor of Medicine. He had a large and influential practice in the neighbourhood of Edinburgh, was appointed by Charles II Geographer Royal for Scotland, and left considerable literary remains, dealing especially with the natural history and archæology of Scotland.

Sir Andrew Balfour (1630–94) studied natural history and medicine at St. Andrews and later at Oxford, Paris, Montpellier, Padua and Caen, where he took the degree of M.D. in 1661. About 1676 he returned to Edinburgh to practise, and here he devoted himself chiefly to botany. Along with Sibbald he was responsible for the laying out of three physic gardens, which became an important activity of the city. The Town Council—recognising that the design of a physic garden would "prove exceedinglie profitable for the instruction of youth in that most necessary though hitherto much neglected pairt of the naturall historie and knowledge wherein the health of all persons whether it be for food, or medicin, is so nearlie concerned"—appointed Mr James Sutherland as overseer of the gardens under Sibbald and Balfour. Subsequently in 1676 Sutherland was made Professor of Botany, the first Professorship to be instituted in the coming Medical School. These physic gardens thus begun have not only proved a great source of commercial revenue in making Edinburgh one of the chief centres of the drug market, but have been of the highest importance to scientific botany. This, however, belongs to botany rather than to medicine.

Sir Archibald Stevenson was an Edinburgh physician intimately associated with Sibbald and Balfour in another important project, the foundation of the College of Physicians, for which a charter was obtained from Charles II by the mediation of the Duke of York in 1681. To this project both the Universities and the Bishops were at first hostile, but they were gradually won over to withdraw their opposition.

Dr Archibald Pitcairne (1652–1713) was perhaps the most celebrated Edinburgh physician of the time. Beginning the pursuit of Law he went to study in Paris, and there took to Medicine. From 1675 to 1680 he studied Medicine in that city, and in the latter year became M.D. of Rheims. On the inducement of his friend, David Gregory, Professor of Mathematics at Edinburgh, he devoted himself with great assiduity

SIR JAMES Y. SIMPSON.

to mathematics, becoming later, like Borelli in Italy, one of the founders of the Iatro-mechanical or Iatro-mathematical school of thought. The system developed from Harvey's demonstration of the circulation; for when the importance of this dynamic principle was grasped, in contradistinction to that of the leisurely ebb and flow of humours, its adherents attempted to prove that all the bodily activities, including those even of the nervous system and of digestion, were mere mechanical exercises. Although this idea could not persist for long, it formed for the century after Harvey a fruitful working hypothesis. Pitcairne threw himself into this controversy with zest, and his attitude is indicated by the title of an attack made on him by Sir Edward Eizat in *Apollo Mathematicus, or the Art of Curing Diseases by the Mathematics* (1695). Pitcairne was one of the original members of the Royal College of Physicians in 1681, and in 1685 he, Sir Robert Sibbald and Dr James Halket were made the first three Professors of Medicine in the Town's College, or, as it now began to be called, the University of Edinburgh. These Professors of Medicine were provided with lecture-rooms, but were unsalaried. Pitcairne's eminence as one of the protagonists of the Iatro-mathematical School procured for him in 1692 an invitation from the University of Leyden to assume the Chair of Medicine at that celebrated University, which he accepted. There he lectured till 1694, when he returned to Edinburgh for family reasons. The fact that the infant school of Edinburgh furnished a Professor to the old-established chair in Leyden must have given a great uplift to the former, still more the fact that Pitcairne had many men among his pupils who afterwards rose to fame, notably Mead and Boerhaave. Pitcairne's writings included numerous polemical pamphlets, poems, and dissertations on medical subjects, as, for example, on the *Quantity of the Blood*, the *Motion of the Stomach*, and especially a dissertation upon the *Cure of Fevers*. This was an important contribution to the medicine of that day, when fevers formed two-thirds of all diseases.

Sir Thomas Burnet (1632–1715) was another of the group who founded the College of Physicians. The son of an Edinburgh advocate prominent in the times of the Civil War, he was the brother of Bishop Gilbert Burnet, celebrated for his share in the revolt against James II, and for bringing over William of Orange. Thomas Burnet took his M.D. diploma at Montpellier in 1659, was physician to Charles II and to Queen Anne in Scotland, and was celebrated all over Europe for his highly popular compendium of medicine, the *Thesaurus Medicinae* (1673).

An important early activity of the developing medical school was the issue of an official Edinburgh Pharmacopœia by the College of Physicians in 1699. The first pharmacopœia to appear had been that of London in 1618, and for the simplicity of its preparations and comparative absence of "dreck-apoteke" that of Edinburgh compares very favourably with the current London edition.

Such, then, were the beginnings of the Royal College of Physicians and of the Medical School at Edinburgh, which came into being not by fortuitous influences, but through determined organisation by a group of unusually capable men. By the year 1700 there were Professors of Botany and of Medicine, a Physic Garden and lectures of a kind upon Anatomy, these being, as we have seen, the necessary elements for a medical degree. The importance that chemistry had attained in the hands of Sylvius and others on the Continent was further recognised by the appointment of Dr Crawford as Professor of this subject in 1713.

This medical school was not effective for attracting or dealing with any large number of students, and in 1720 Alexander Monro was appointed Professor of Anatomy; this being followed very soon (1726) by the appointment of Andrew St. Clair and John Rutherford as Professors of Medicine and Institutes of Medicine, Andrew Plummer and John Innes as Professors of Chemistry and Joseph Gibson as Professor of Midwifery. These had been pupils of the celebrated Boerhaave in Leyden. The steady growth of the School is shown by the number of students attending the class of anatomy, which rose from 57 in 1720 to 83 in 1730, 130 in 1740, 158 in 1750, 342 in 1790 and over 800 in 1807. As will be pointed out later, from this time Edinburgh became distinguished as a centre for anatomical research and teaching, second only to the position into which London was raised by the brothers Hunter and their followers.

Another celebrated teacher, distinguished also for his work as a neurologist, was Robert Whytt, who acted as Professor of Medicine from 1747 to 1766. In his earlier days Whytt had published a treatise upon the cure of stone in the bladder, then a very important disease. In 1751 appeared his work, *On the Vital and Other Involuntary Motions of Animals*, which attracted the attention of physiologists all over Europe and provoked a controversy with the great hierarch of physiology, Haller. In this book Whytt for the first time drew attention to the importance of the sympathetic nervous system, and threw aside the doctrine of Stahl that the rational soul is the cause of all involuntary motions in animals, ascribing such movements to "the effect of a stimulus acting on an unconscious sentient principle." His greatest work, *On Nervous, Hypochondriac, or Hysteric Diseases, to which are Prefixed some Remarks on the Sympathy of the Nerves*, appeared in 1764, and was shortly after translated into French. Whytt also published several essays on physiological and clinical subjects, of which his *Observations on Dropsy of the Brain* gives the earliest account of tuberculous meningitis.

He was succeeded in the Chair of Institutes of Medicine in 1766 by William Cullen, an eminent teacher and consultant who did for the developing Edinburgh School what Boerhaave had done for Leyden. Cullen had studied in Glasgow, practised for a time in Hamilton, where he had William Hunter for a pupil, and subsequently moved to Glasgow, where he lectured upon Medicine and other subjects, and had Joseph Black as a pupil. These two men remained his devoted friends through life. In 1755 he was elected Professor of Chemistry in Edinburgh, a chair in which ten years later he was succeeded by Black. Fortunately Cullen, like his predecessors, was highly successful as a clinical lecturer, and for many years (1773–90), while he held the Chair of Practice of Medicine, he was the mainstay of the Edinburgh School. He took an active part in preparing the new edition of the *Edinburgh Pharmacopœia*, issued in 1774, and in obtaining a new hall for the College of Physicians. In 1783 his persevering exertions secured the incorporation of the Philosophical Society as the Royal Society of Edinburgh. He was not distinguished as an anatomist or physiologist or as an observer of clinical facts. The influence he exerted on the public mind and the great attraction that he exercised in bringing students from a distance were due to his clearness of perception, sound reasoning and judgement more than to any originality. As a lecturer he had powers of interesting his students and inspiring them with enthusiasm. One of his pupils highly commends his excellent arrangement, his memory of facts, and the ease, vivacity, variety and force of his lectures. He lived at a time when medical science had been enriched by many as yet unrelated facts, and when medical practice was driven hither and thither by conflicting theories and systems. These his clear mind and power of expression enabled him to codify and set in their proper places. His principal published works were the *First Lines on the Practice of Physic* and his *Nosology* (1769). The latter aimed at a rigid classification of diseases by their symptoms on the same principle as Linnæus had (1735–53) adopted for classifying plants. It arranges all diseases by classes, orders, genera and species, and regarding them as fixed entities makes in a sense a system of the whole of medicine. Although at the present day diseases are arranged on a causal system, and Cullen's classification is forgotten, it undoubtedly greatly simplified medicine and established his reputation during his lifetime and for half a century afterwards.

The friendship that subsisted between Cullen and his pupil, Joseph Black, has been mentioned ; and Black's career and work are detailed in the section on Chemistry.

Another pupil of Cullen, named John Brown, should be mentioned in connection with the so-called "Brunonian System," not because this made any real addition to medical science, but because it illustrates a frequently recurring phase of medical opinion and one which in its time obtained a great number of adherents. Brown, acceding to the ever-present demand for some system in medicine according to which definite remedies may be applied to definite symptoms, revived the old Asklepiadean methodism of the Roman Empire ; which had shortly before been adopted by Hoffmann of Halle. Diseases are, according to the Brunonian System, to be classified as "sthenic" or "asthenic," according as the vital condition of "excitement" is increased or diminished, and the tissues constricted or relaxed. Treatment is to be administered by depressing drugs in the one case and by stimulation in the other. This theory, so simple and so complete as far as it went, not only obtained many adherents among the students in Edinburgh, but gained a firm footing in some of the universities of Germany and Italy till as late as the early part of the nineteenth century.

Cullen was succeeded in the Chair of Practice of Medicine by James Gregory, who was brilliant and witty as a teacher, and one of the great polemic writers of his day, but who added nothing to medical knowledge or practice beyond giving his name to a favourite domestic stomachic, the powder composed of magnesia, rhubarb and ginger. As Edinburgh had been since Cullen's time the chief medical school of fame and resort in Britain, students flocked to it from all parts of the British Isles and the Colonies, so that these became flooded with practitioners who carried out Gregory's doctrines of free blood-letting, cold affusions, brisk purging, frequent blistering and the use of tartar emetic.

A more important figure in medical history was Andrew Duncan, Senior (1744–1828), who as an extra-academical lecturer on Medicine founded a dispensary for the treatment of the poor, which was later incorporated as the Royal Public Dispensary. He also in 1773 commenced the publication of a periodical named *Medical and Philosophical Commentaries*, a quarterly journal of medicine issued by a Society of which he was secretary ; later the publication was entitled *Annals of Medicine* ; and in 1804 it merged into the *Edinburgh Medical and Surgical Journal*, edited by his son, Andrew Duncan, Junior. This periodical has survived to the present day as the organ of the Edinburgh Medical School under the title of the *Edinburgh Medical Journal*.

In 1792 Andrew Duncan, being now Professor of the Institutes of Medicine, proposed the erection of a public lunatic asylum in Edinburgh. It is important to note that this proposal was made some nine years before the appearance of Pinel's *Traité medico-philosophique sur l'alientation mentale* (1801), which is generally regarded as the first step in the direction of humane treatment for this unfortunate class of sufferers. Duncan had been led to his suggestion after hearing of the miserable death of Robert Fergusson, the poet, while insane, in the common workhouse in 1774. After many difficulties had been surmounted, the project was at last accomplished. A Royal Charter was obtained in 1807, together with a grant of £2000 by Government from the forfeited Highland estates, and by these means a lunatic asylum was built on modern humane lines at Morningside. Duncan also founded and was the first President of the Edinburgh Medico-Chirurgical Society in 1821. Apart from his public activities, Duncan wrote largely, his best known works being

Elements of Therapeutics, Medical Cases and *The New Dispensatory.*

Andrew Duncan, Junior, in 1803 brought out the *Edinburgh New Dispensatory,* which went through ten editions, was translated into French and German, and was extensively used in the United States. In 1807 he was appointed to the newly created Chair of Medical Jurisprudence, but attendance on this subject was not at that time made compulsory for students, though in the Commission creating the Professorship it was stated that the subject was "taught in every University of reputation on the continent of Europe."

The Duncans, father and son, were succeeded in the Chair of the Institutes of Medicine by William Pulteney Alison, who later became Professor of Medicine in 1842. Alison was brother of Sir Archibald Alison, the eminent historian of Europe. His reports of the New Town Dispensary (1817–19) were important contributions to the knowledge of fevers, and especially are of value in showing the modification of smallpox caused by vaccination which at that time was a novel method of treatment. He published the substance of his physiological lectures in *Outlines of Physiology* (1831), and in his teaching of this subject he postulated the existence of "vital forces" inherent in living tissues; vital contraction he held to be a property of certain tissues; while vital attraction was shown in every part of the organism, at every moment of nutritive, secretive and absorbent change. Alison explained inflammation and other phenomena of disease in the same way. These matters are dealt with in many of his writings, but modern thought has drifted away from his standpoint, which appears to be little relevant to vital phenomena as now conceived. Of much greater importance than Alison's medico-philosophic writings were his practical activities and treatises. The latter were all concerned in one way or another with the amelioration of the Scottish poor. From the beginning of his medical experience Alison had been deeply impressed with the manner in which poverty and unfavourable social conditions assist in the spread of disease. This was brought out in his *Observations on the Management of the Poor in Scotland, and its Effects on the Health of the Great Towns* (1840). After prolonged agitation a Royal Commission of inquiry was appointed in 1844, and an Act was passed in 1845 embodying most of what Alison had striven for. His work was not only of great value to the poorer classes of his time, but was an important precursor of much of the social legislation at the present day.

It should be remembered that in the Edinburgh Medical School there has been from the beginning a solid body of teaching, practice and research, outside and independent of the University. As we have seen, Sibbald, Balfour and their associates in the late seventeenth century had laid out physic gardens, given instruction in Medicine, and published medical treatises before the Town's College assumed them as Professors; the same applies to the teachers of Anatomy in the Surgeon's Corporation, of whom Eliot, Drummond and M'Gill were, in the early years of the eighteenth century, taken over as Professors of Anatomy in the Town's College. This Extra-Mural School did not give place to the University, but continued to increase in numbers and in activity as the Town's College developed into the University of Edinburgh. Most of the medical Professors in the latter have been chosen from among this body of teachers, and it has been the policy of the University to recognise the lecture courses of these teachers as soon as they were licensed by the College of Physicians or of Surgeons, as the case might be. This large body of teachers has steadily augmented the sum of medical knowledge.

The relationships of the Academical and Extra-Academical Schools are well illustrated in the development of the science of Anatomy, to which some detailed reference may now be made. As already pointed out, the early days of anatomical teaching in Edinburgh go back to 1505. Among the anatomists of the seventeenth century were James Borthwick, Robert Eliot, Alexander Menteith and Archibald Pitcairne. Robert Eliot in 1705 was made the first Professor of Anatomy in the Town's College, and in 1708 Adam Drummond was conjoined with him in office. On the death of Eliot in 1716, John M'Gill was conjoined with Drummond till 1720, when both, being occupied with other business, resigned in favour of Alexander Monro.

Alexander Monro *primus* (1697–1767) had been brought up by his father, John Monro, an old Army Surgeon and recent member of the new College of Physicians, with the view of teaching anatomy in Edinburgh. Returning to Edinburgh, after studying Anatomy under Cheselden in London, and Medicine in Paris and at Leyden under Boerhaave, he was appointed, in 1720, Professor of Anatomy in the Town's College. Along with Lord Provost Drummond he was instrumental in founding the Royal Infirmary, opened in 1729 and rebuilt in 1741. Here he, along with Rutherford, introduced the methods of bedside teaching and of giving clinical lectures they had learned at Leyden, and he was for many years the most important professor in the developing medical school. His chief work was a treatise on *Osteology*, which went through several editions, and he published some fifty papers on minor subjects of Anatomy, Surgery and Medicine.

His son, Alexander Monro *secundus* (1733–1817), was both more popular as a lecturer and more distinguished for his publications than the father. Brought up with the idea of succeeding to the Anatomical Chair, he was educated under William Hunter in London; and later at Paris, Leyden and Berlin. He was one of the earliest (1758) to describe the general communications of the lymphatic system; and in 1783 he published his important treatise on the *Structure and Functions of the Nervous System*. In this work occurs his description of the communication between the lateral ventricles, through the name of which, "foramen of Monro," he is known to every medical student; he had observed it in a case of dropsy of the ventricles, where it was greatly distended. In 1788 he published his observations on the *Bursae Mucosae of the Human Body*, the first full description of these cavities. He was also greatly interested in the action of drugs, as shown by his *Experiments on the Nervous System with Opium and Metalline Substances* (1793); and he devoted much attention to comparative anatomy, as evidenced by his *Structure and Physiology of Fishes explained and compared with those of Man and other Animals* (1785), a branch of Anatomy which later attracted a great deal of attention in Edinburgh. His last book, *Three Treatises on the Brain, the Eye and the Ear*, appeared in 1797.

His son, Alexander Monro *tertius* (1773–1859), continued the tenure by the Monro family of the Anatomical Chair at Edinburgh through a period of one hundred and twenty-six years. Many distinguished men were his pupils, though during his tenure of office it was the practice of the students to pay the fee of his class but obtain their instruction from the more popular extra-academical teachers. A number of writings on anatomical and other subjects issued from his pen, but none was of any permanent value.

Monro *secundus* had been not only a popular and successful teacher of Anatomy, but he enjoyed a great private practice as consulting physician, more lucrative probably than that of his contemporary Cullen. As he did not practise surgery, though he gave lectures on this subject, he left a good field for the extra-academical surgeons. These, and especially the brothers John and Charles Bell, saw the great importance to the surgeon of a practical training in Anatomy, and soon began to invade the latter subject. Together these brothers dissected, taught, and published between 1793 and 1802 their *Anatomy of the Human Body*, which went through numerous editions. In 1794 John Bell brought out his *Engravings of the Bones, Muscles and Joints*, drawn and engraved by himself. Charles Bell assisted in teaching his brother's anatomical class, and the two brothers virtually created the subject of surgical anatomy. Charles Bell's fame rests chiefly on physiological researches, which place him on equality with Harvey. It is somewhat difficult to separate the work done in his Edinburgh periods from that done while he was in London. He was born and lived in Edinburgh till 1804, when, at the age of thirty, he went to London, whence he returned to become Professor of Surgery at Edinburgh in 1836. Before he left Edinburgh he had been at work on the nervous system and on the arteries, and, as already stated, in 1804 he published the account of the nervous system and special senses in the *Anatomy of the Human Body*, written by himself and his brother John Bell. Most of his celebrated *Anatomy of Expression* also belongs to this period. Both of the brothers, by the way, were expert draughtsmen, like another Edinburgh physiologist, Allen Thomson (1809–84), whose sketches may still be seen illustrating present-day text-books. While in London Charles Bell, in 1811, published privately his *New Idea of the Anatomy of the Brain, submitted for the Observations of his Friends by Charles Bell, F.R.S.E.* It contained the first description of the varying function in the anterior and posterior nerve roots. . . . "I found that injury done to the anterior portion of the spinal marrow, convulsed the animal more certainly than injury done to the posterior portion; but I found it difficult to make the experiment without injuring both portions. . . . On laying bare the roots of the spinal nerves, I found that I could cut across the posterior fasciculus of nerves, which took its origin from the posterior portion of the spinal marrow, without convulsing the muscles of the back; but that on touching the anterior fasciculus with the point of the knife, the muscles of the back were immediately convulsed."

It will be observed that Bell does not definitely specify the function of the posterior roots, which he believed to be connected with the cerebellum. This was discovered by Magendie in 1822, eleven years after Bell's publication of the nature of the anterior roots. On his return to Edinburgh in 1836, Bell published his *Nervous System of the Human Body*, in which he describes his famous researches on the nerves of the face and respiration, and gives the first account of the effects produced by paralysis of the seventh nerve (Bell's palsy) as follows :

"It appears that whenever the action of any of the muscles of the face is associated with the act of breathing, it is performed through the operation of this respiratory nerve, or *portio dura*. I cut a tumour from before the ear of a coachman. A branch of the nerve which goes to the angle of the mouth was divided. Some time after he returned to thank me for ridding him of a formidable disease, but complained that he could not whistle to his horses."

Another of the celebrated extra-academical teachers of Anatomy during the Monro regime, was Dr Barclay, who first studied Divinity, and taking up Medicine later, was, from 1797 to 1825, a successful teacher of Anatomy. He was a talented comparative anatomist, and left a valuable museum of human and comparative anatomy, as well as numerous treatises. Among the latter were *A New Anatomical Nomenclature, The Muscular Motions of the Human Body, The Arteries of the Human Body, An Inquiry concerning Life and Organisation.* For eleven years of Barclay's time as a teacher (1806–19) a rival teacher to him and the Monros was Dr John Gordon, who published several works, of which the best known was a treatise written in opposition to the phrenologists Gall and Spurzheim, entitled *The Structure of the Brain, comprising an Estimate of the Claims of Drs Gall and Spurzheim to Discovery in the Anatomy of that Organ.* John Innes and Andrew Fyfe, who acted successively as demonstrators to Monro *secundus*, were well-known as authors of successful text-books on Anatomy.

During the later years of tenure of the Chair by Monro *tertius*, the number of medical students matriculating in the University sank to little more than one-third of what it had been when he succeeded to the professorship, and in this period a large number of teachers appeared, such as Cullen, Aitkin, Lizars, Liston, Syme, Knox. All of these, however, with the exception of Knox, treated Anatomy more as a stepping-stone to operative surgery, and with them we have no concern here.

Robert Knox (1791–1862) succeeded Barclay as a lecturer on Anatomy in 1825, and was so popular a lecturer that his class in a few years numbered over five hundred students. He had the misfortune to be involved by the murders of Burke and Hare. Though he was exonerated from knowledge of their culpability, unpopularity fastened upon him, which gradually proved his ruin. Apart from his brilliance as a lecturer, he was known in his lifetime for several anatomical and ethnographical works, *e.g.*, *The Edinburgh Dissector*, *The Races of Men*, *A Manual of Artistic Anatomy*, *A Manual of Human Anatomy*, etc., but none of these is of any great permanent value.

Other extra-academical lecturers of a slightly later period were Dr Sharpey, who lectured on Anatomy from 1832 to 1836, and who, during his Edinburgh period, discovered the "cilia" possessed by some mucous membranes. Allen Thomson, another extra-academical lecturer on Anatomy along with Sharpey, and Dr Martin Barry were two of the earliest inquirers with the help of the microscope into the mysteries of the developing ovum, and many fundamental discoveries in embryology were made by them.

The Edinburgh School played a notable part in the great movement of the first half of the nineteenth century, which resulted in the recognition of the cell as the morphological unit in vital processes. This it did through the work of John Goodsir. Goodsir (1814–67) acted first as Curator of the College of Surgeons' Museum, then in a similar capacity to the University, and finally as Professor of Anatomy from 1846 to 1867. In his early days, like others of the time, he was interested in parasitology, and the sarcina ventriculi and the fungus responsible for potato blight were two of his discoveries. About the period 1842–45 he published a number of papers dealing with the activities of the cell. Up to this time it was generally accepted that new cells were developed by a process of precipitation of granules in a fluid exudate. Goodsir, on the contrary, not only advocated the importance of the cell as a centre of nutrition, but considered that the organism was divided up into territories of cells presided over by one central cell. Virchow recognised his indebtedness to Goodsir by dedicating to him his *Cellular Pathologie* (1858), in which he calls Goodsir "one of the most acute observers of cell-life." These cellular doctrines are to be found in Goodsir's *Centres of Nutrition, Absorption and Ulceration, Ulceration in Articular Cartilages, Secreting Structures, Diseased Conditions of the Intestinal Glands*, etc. His treatises on natural history subjects were numerous, as were also those on Morphological and Teleological Anatomy, such, for example, as that *On the Mechanism of the Knee-Joint, On the Morphological Constitution of Limbs*, etc.

To Goodsir's time belongs another distinguished representative of the extramural school who subsequently became Professor of the Institutes of Medicine in the University (1848)—John Hughes Bennett (1812–75). He taught Physiology and Medicine for over a quarter of a century, published a text-book on Medicine which was widely read, but the chief scientific achievements associated with his name are his original description of the disease leucocythæmia, and the great change to which his investigations led in the current treatment of pneumonia. Leucocythæmia was the first disease of the blood to be described (1845), and its recognition opened up an entirely new branch of Medicine (Addison described pernicious anæmia four years later in 1849).

The question of priority in discovery of leucocythæmia is sometimes debated, for, like other discoveries in medicine, it was made simultaneously by different men, three cases of leucocythæmia being independently recorded for the first time in the year 1845. Hughes Bennett's history of the matter, given in his treatise on Leucocythæmia of 1852, shows that the credit of priority belongs to him.

Bennett's treatise on *The Restorative Treatment of Pneumonia*, published in 1865 when he was Professor of the Institutes of Medicine, belongs to a type of medical research much more difficult to appraise. The practice of bleeding had come down from the eighteenth century as a moderate method, and had been developed by the French School of Broussais, by Gregory of Edinburgh and others into a powerful weakening or "antiphlogistic" regime which was supposed to be requisite in order to abort the fever. Hughes Bennett's treatise is a masterly survey of different methods then in vogue for treating pneumonia, which he compares by means of the statistical plan of Louis. By showing that the method of profuse bleeding was followed by death in one case out of three, while of one hundred and twenty-nine cases treated by him on the "restorative" principle only four had died, he did more than any one else to banish excessive bleeding as a routine method of treatment.

We may now consider some of the other outstanding figures in the Edinburgh Medical School of the middle period of the nineteenth century.

Sir James Young Simpson (1811–70), who became Professor of Midwifery at Edinburgh in 1840, made many contributions to extend and improve that branch especially. He introduced the uterine sound (1843), iron wire sutures (1858), the long obstetric forceps and other instruments, acupressure (1860), the practice of version for certain varieties of deformed pelvis. He also made valuable contributions to medical literature on such subjects as hermaphroditism and leprosy in

Scotland, but his name is especially associated with the introduction of chloroform into obstetric practice, and indeed with fighting the battle against prejudice for the use of anæsthetics generally in Britain. Since the steps by which ether and chloroform were introduced into obstetrics, prior to their adoption for surgery, are not generally known, it is of interest to set them down here in Simpson's own words.

"If we try to put into a summarised form the data which we have been discussing regarding the introduction of anæsthesia in America and this country, it appears to me that we might correctly state the whole matter as follows:

"1. That on the 11th December 1844 Dr Wells had at Hartford, by his own desire and suggestion, one of his upper molar teeth extracted without any pain, in consequence of his having deeply breathed nitrous oxide gas for the purpose, as suggested nearly half a century before by Sir Humphry Davy.

"2. That after having with others proved, in a limited series of cases, the anæsthetic powers of nitrous oxide gas, Dr Wells proceeded to Boston to lay his discovery before the Medical School and Hospital there, but was unsuccessful in the single attempt which he made, in consequence of the gas-bag being removed too soon, and that he was hooted away by his audience, as if the whole matter were an imposition, and was totally discouraged.

"3. That Dr Wells's former pupil and partner, Dr Morton of Boston, was present with Dr Wells when he made his experiments there.

"4. That on the 30th September 1846 Dr Morton extracted a tooth without any pain, whilst the patient was breathing sulphuric ether, this fact and discovery of itself making a NEW ERA in anæsthetics and in surgery.

"5. That within a few weeks the vapour of sulphuric ether was tried in a number of instances of surgical operations in Boston—Dr Morton being generally the administrator—and ether vapour was established as a successful anæsthetic in dentistry and surgery.

"6. That in January, and the subsequent spring months, 1847, the application of sulphuric ether as an anæsthetic in midwifery was introduced, described in our medical journals, and fully established in Edinburgh, before any case with it was tried in Boston or America.

"7. That on the 15th November 1847 the anæsthetic effects of chloroform were discovered in Edinburgh, and that it swiftly superseded in Scotland and elsewhere the use of sulphuric ether, and extended rapidly and greatly the practice of anæsthesia in surgery, midwifery, etc."

In 1816 the Hanoverian Sertürner had discovered the alkaline base "morphium" in opium, and in April 1831 Dr William Gregory, afterwards Professor of Chemistry, published in the *Edinburgh Medical and Surgical Journal* his valuable discovery of the preparation of hydrochlorate of morphia without the use of alcohol or any other solvent than water. Morphia, till then used in the form of acetate, had made little progress in Britain, because too expensive, and probably also by no means always pure. But Gregory's process supplied a soporific dose of morphia at no greater cost than the equivalent dose of laudanum, and in a state of great purity. As is well known, the hydrochlorate and the subsequently prepared sulphate of morphia have largely superseded in use the other purified galenical preparations of opium. As a development of this discovery, Edinburgh has become the chief commercial centre in the United Kingdom for the manufacture of the active alkaloidal principles derived from numerous plants. William Gregory belonged to a family of which many representatives practised or held professorial chairs in Edinburgh, of whom James Gregory has already been mentioned. The first of the succession was James Gregory, the mathematician (see page 5).

William Gregory's work was not only intrinsically important, but it is noteworthy in that another of the great nineteenth-century personalities of the Edinburgh School was associated with its development. This was Dr (afterwards Sir) Robert Christison (1797–1882), from 1822 to 1832 Professor of Medical Jurisprudence, and from 1832 to 1877 Professor of Materia Medica. In Medical Jurisprudence his investigations on bruising of the living body, conducted with reference to the trial of Burke and Hare, and on burns sustained before and after death, belong to the classics of this subject. In the case of bruising, his experiments, which showed that bruises cannot be inflicted after death, formed the crucial point for the conviction of the murderers in this case. In toxicology, his work on the effects of oxalic acid, on the action of water on lead, and on cases of arsenic poisoning, were of great value. Christison had spent a period of his early life in study, mainly chemical, at Paris, where Magendie was then introducing the subject of experimental pharmacology and Orfila was busy with toxicology. His partiality to chemical and toxicological science is shown in the *Dispensatory*, which he published in 1842 ; this was founded to some extent upon the Dispensatory of his predecessor in the Chair of Materia Medica, Andrew Duncan, and constituted a kind of commentary upon the pharmacopœias of Edinburgh and other places, containing also records of Christison's own experiments and observations. This work prepared the way for the first Pharmacopœia of Great Britain and Ireland, issued in 1864 by a Committee of the General Medical Council, of which Christison acted as Chairman. Among his best known pharmacological discoveries were that of conine, the active principle of hemlock (1836), of the action of Calabar bean (1855) and of the therapeutic uses of digitaline (1855) ; for though he did not originally isolate this active principle, he was the first in this country to point out its valuable properties, especially as a diuretic. Christison's work on the action of conine is interesting as being one of the earliest pharmacological experiments to be done in this country. He showed that it acted by abolishing the functions of the spinal cord, the action being "the counterpart of the action of nux vomica and its alkaloid strychnia." Other active drugs investigated by Christison were Calabar bean, coca leaves, and especially the effects and properties of opium from various sources and of different kinds of wine.

An important advance in the knowledge of nervous and psychic disorders was made by Thomas Laycock, Professor of Medicine from 1855 to 1876. His *Treatise on the Nervous Diseases of Women* (1840) had been one of the first contributions (preceding Charcot) to the modern view of hysteria. In 1844, in a paper read before the British Association at York, he had formulated the theory of reflex action of the brain by which he accounted for the phenomena of delirium, dreams and somnambulism. His *Mind and Brain* (1859) prepared the way for the study of unconscious cerebration, to which he afterwards chiefly devoted himself, and in which he described mental phenomena that have received due recognition only in the last few years in connection with the great numbers of nervous cases arising out of the War.

In concluding this notice mention may be made of a minor though far-reaching contribution by a member of the Edinburgh School to practical medicine. Alexander Wood, an extramural lecturer on Medicine at Edinburgh, was the first in Britain to use the hypodermic syringe, though priority of discovery cannot be claimed for him, since Pravaz had already used this form of medication in 1851 and published a description of his syringe in 1853. The idea of administering morphia hypodermically for the relief of pain appears to have occurred independently in 1853 to Wood, who constructed a small syringe on the plan of the "sting of a bee," for this purpose. Subsequently he extended its application to the administration of atropine and other substances in his *New Method of Treating Neuralgia* *by Subcutaneous Injection* (1855). He enjoys at all events the merit of having been the first to introduce this now universal method in Great Britain.

J. D. C.

SURGERY

It may be that Modern Surgery is more properly placed among the Arts than among the Sciences, but, even as a craft, its progress must ever depend upon the soundness of the scientific principles upon which its practice is based. From the time it began to emerge from its purely empirical stage, every real advance of Surgery as an applied art has been directly traceable to some permanent addition made to exact knowledge. Technical skill and manipulative dexterity have doubtless counted for much, but even in periods when these talents were most highly developed, progress has been arrested for want of light that could only be obtained through scientific inquiry. Advances in scientific knowledge are not the product of any separate school of thought, their practical applications cannot be confined within the walls of any seat of learning, nor can any individual claim the sole credit for a forward step. If the surgeons of Edinburgh can claim to have advanced their calling along scientific lines, it is only because they have worked upon the common body of knowledge; some by revealing new facts, some by discerning the bearing of facts revealed by others, and some by giving these their practical application.

The intimate association between Surgery and Anatomy is traditional in Edinburgh; indeed, the very foundation of the School may be traced to the steps that were taken by the early surgeons to ensure that their practice should be based upon an accurate knowledge of the structure of the human body. As far back as 1505, before the fathers of Anatomy, Vesalius and Fallopius, were born, and before the divines had met at Salamanca "to determine if it were consistent with conscience to dissect a human body for the purposes of science," the Corporation of "Chirurgeanes and Barbouris" of Edinburgh petitioned the Town Council "that we may have anis in the yeir ane condampnit man after he be deid, to mak antomea of, quairthrow we may heif experience, Ilk ane to instruct utheris, And we sall do suffrage for the soule." This they did on the ground that "every man aucht to knaw the nature and substance of every thing thatt he wirkis or ellis he is negligent."

The granting of this petition by the Provost and Council in 1505 was the earliest of the many enlightened acts that have characterised the policy of our city fathers in relation to medical education, and the first tie in the close bond of union that exists between Town and Gown in our city to-day.

When the Town Council granted them their "Seal of Cause," the Surgeons were combined with the Barbers in a single corporation, and the interests of the two sections frequently clashed. The provision of anatomical material stimulated the surgeons to improve their knowledge and skill, so that they came to "knaw all the vaynis in manis bodie" and were thus able to "mak flewbothomea in dew tyme." The duties proper to the barber were "to clip, cow, and shave the lieges," and to these the surgeons vainly sought to confine them. The attempts to define the respective spheres of activity of the two crafts led to much friction, until finally they were separated by a decree of the Lords of Session in 1722.

Meanwhile the body of a single malefactor in the year failed to meet the needs of the growing School of Anatomy, and the Town Council made a further grant of "these bodies that dye in the correction-house" and "the bodies of fundlings that dye upon the breast . . . for the encouragement of so necessary a work as the improving of Anatomy." Later, yet another demand was made, for "the bodies of fundlings who die betwixt the time that they are weaned and their being put to schools or trades; also the dead bodies of such as are stiflet in the birth; which are exposed and have none to owne them; also the dead bodies of such as are *felo de se*, and likewise such as are put to death by sentence of the magistrat, and have none to owne them."

In granting this last request the Town Council made it conditional on the Corporation building an anatomical theatre and publicly holding in it once a year "ane anatomical dissection as much as can be showen upon one body." The first public dissection, which took place in 1703, marks a step forward in the development of the surgeons' anatomical school. No longer was Anatomy to be a purely technical branch of study designed merely to improve the craftsmanship of the surgeons and their apprentices; it was now to become a subject of general education. The records that have come down to us do not show to what extent the people of Edinburgh embraced the opportunities thus afforded them of studying anthropology, but there is satisfactory evidence that the standard of surgical practice was raised, and in this way the public derived benefit.

For two hundred years the surgeons continued to utilise their anatomical material in accordance with the condition on which it had originally been granted them—"ilk ane to instruct utheris,"—but in 1705 the teaching of Anatomy was placed in the hands of one man, when the Incorporation selected Robert Eliot to instruct their apprentices and servants; and the Town Council, who confirmed this appointment, made Eliot Professor in the Town's College at an annual salary of fifteen pounds. Adam Drummond, John M'Gill, and Alexander Monro *primus* were successively selected by the surgeons to fill the Chair of Anatomy, and were accepted by the Town Council.

It cannot be claimed that, prior to the advent of the first Monro, members of the Edinburgh School had made any outstanding contributions to anatomical science; but by disseminating such knowledge as was then current, and by encouraging the study of the subject among their pupils, they helped to lay a sound scientific foundation for the development of a School of Surgery.

The time for this was ripe, and the men were ready, but circumstances conspired to delay its fulfilment. The very success with which the surgeons had nurtured the School of Anatomy for two centuries proved their own undoing. It came about in this way. After Alexander Monro had been the Professor of Anatomy at Surgeon's Square for five years, a rumour got abroad that the graves in the city churchyards were being desecrated to provide anatomical material, and, to avoid the vengeance of the mob, Monro moved himself and his valuable collection of preparations to the more secure keeping of the University. Soon after this (1726) a Medical Faculty was founded within the University, and Monro was appointed Professor of Anatomy, with the additional duty of teaching Surgery. But Monro being no surgeon, his teaching of the subject was perfunctory, and his brilliant talents were entirely devoted to his anatomical work. After filling the Chair for thirty-eight years, he was succeeded by his son Alexander *secundus* (an even more distinguished anatomist), on similar terms, and with results even less satisfactory to Surgery, for he not only failed to teach the subject himself, but for fifty-four years successfully opposed the establishment of a Professorship of Surgery within the University.

The third of the Monro dynasty in time succeeded his father, and delivered the official course of surgical instruction within the University, while outside he practised as a physician. Thus did the official teaching of Surgery remain in thraldom to Anatomy for a hundred and ten years. But even the surgeons are free to remember with gratitude and pride the lustre which the anatomical work of the Monros shed upon the Edinburgh School.

Surgery did not, however, stand still in Edinburgh throughout the long reign of the Monros. During the second half of the eighteenth century the stimulus given to surgical progress by Petit, Chopart, Desault and other leaders of the French School roused the younger surgeons of Edinburgh, and some were attracted to Paris to study under these masters. Among them was Benjamin Bell (1749–1806), the first of a long succession of Bells who worthily upheld the traditions of Surgery in Edinburgh from 1770 till 1911, when Joseph Bell, the last of the race, died. Benjamin Bell is looked upon as the "father of the surgical school," and in his lifetime he exerted a considerable influence on the progress of his art. He published between 1783 and 1788 the first *System of Surgery* in the English language: it went through seven editions, was translated into French and German, and was for long the standard English work on Surgery. An accurate observer of clinical phenomena, with an alert and speculative mind, he was in many respects singularly in advance of his times, and if he did not anticipate he at least had glimmerings of some of the great ideas of later days. He advocated the use of measures to diminish the pain of surgical operations; he recognised the danger of admitting air to the contents of abscesses and other collections of matter and devised means of preventing it; he employed systematic rubbing of limbs to prevent as well as to cure stiffness in muscles and joints with all the zeal of a modern masseur; and he introduced new principles in performing amputation of limbs. His most important scientific contribution to Surgery was his demonstration that gonorrhœa and syphilis are separate diseases, and in maintaining this thesis he had to contend with no less an authority than John Hunter.

But for a domestic quarrel between the College of Surgeons and the Managers of the Royal Infirmary, Benjamin Bell's place as the leading surgeon in Edinburgh would have been seriously challenged by his contemporary, of the same surname but of a different family—John Bell (1763–1820), one of the protagonists in a famous battle of words that agitated the academic world of Edinburgh during the first decade of the nineteenth century. In the Extramural School, assisted by his more famous brother, Charles, he pursued the study of Anatomy, largely from the point of view of an applied science, and is generally looked upon as the pioneer of "surgical anatomy." His work on the "anastomosing arteries" and the development of a collateral circulation after ligation of a main arterial trunk had a great influence in limiting the indiscriminate amputation of limbs for gunshot wounds implicating the large blood vessels, which was then the practice. It also led to improvements in methods of amputating when the limb could not be saved, and threw considerable light on the process of healing in wounds. John Bell's *Treatise on Gunshot Wounds,* based on his experience amongst the wounded men of Admiral Duncan's fleet after the battle of Camperdown, and his *Principles of Surgery,* are among the surgical classics.

The claims of Edinburgh on John's younger brother, Charles Bell (1774–1842), are not so easily assessed, and have been discussed in a previous article. While still a student here he published a *System of Dissections,* illustrated by his own drawings, and it is said that "even before he left Edinburgh a suspicion had grown upon his mind that the prevalent opinion regarding the functions of the peripheral nerves was erroneous." The idea thus early implanted bore ample fruit after Charles went to London, and his work on the functions of the nerves placed him in the forefront of scientific discoverers. In 1836 he returned to Edinburgh as Professor of Surgery, but his life's work had been accomplished, and nothing was added to his fame during the six years he filled the Chair.

In the latter part of the eighteenth century also an attempt was made by James Rae, a Deacon of the Incorporation of Surgeons, by means of private lectures on diseases of the teeth, to place the practice of Dentistry on a more scientific basis than it had hitherto enjoyed. Rae was also the first to give a consecutive course of instruction in Clinical Surgery in the Edinburgh School.

Through the advocacy of John Bell, the Crown established, in 1806, a Chair of Military Surgery in the University, and this was successively held by John Thomson (1765–1846) and Sir George Ballingall (1786–1855). It cannot be said that the Professorship justified its existence, and on the death of Ballingall, James Syme had little difficulty in persuading the authorities to abolish it.

Towards the end of the eighteenth century a further development took place in the advance of Surgery. The intensive cultivation of Anatomy which had gone on for over two centuries and a half had given the surgeons an intimate acquaintance with the structure of the body, which enabled them to undertake operations that without this knowledge would have been impracticable. At the same time, means of controlling the loss of blood had gradually been evolved, and more was known of the nature of disease and of the reparative processes. The main obstacle to the performance of such serious operations as then appeared to be justifiable was the limits of endurance of the patient. Surgical anæsthesia was not yet available for the prevention of pain, so the alternative was to shorten the duration of the operation as far as possible. To this end manipulative dexterity was cultivated by surgeons in every possible way, from the practice of amateur carpentry to the playing of the fiddle.

A race of surgeons arose who vied with one another in the rapidity with which they could amputate a limb, excise a jaw, or trepan a skull, and the names of some have come down to us rather on account of their prowess in these directions than through their more purely scientific contributions to Surgery. Not that this was their only claim to remembrance. John Lizars, for example—the first in Scotland to ligate the innominate artery for aneurysm and to perform ovariotomy—was also the first to suggest, although he did not venture to perform, such operations as excision of the prostate gland, puncture of the brain in hydrocephalus, and the injection of air into the pericardium as a remedy for hypertrophy of the heart. Sir William Fergusson, although acclaimed after his death by Sir James Paget as "the greatest practical surgeon of his time," was also the strongest advocate of "conservative surgery," by which he sought to save limbs rather than to sacrifice them; and he devised an operation for cleft palate, which calls for delicate rather than for rapid work, as well as certain operations on the jaws, that are still practised as he directed. Robert Liston, perhaps the most brilliant operator of all, made valuable contributions to the knowledge of fractures, of diseases of bone, and of aneurysms, and after he went to University College Hospital he performed for the first time in England a major operation—amputation through the thigh—under ether anæsthesia.

A new epoch in Surgery opened with the introduction of anæsthesia, and Edinburgh's share in this advance is one of her most cherished traditions. James Young Simpson cannot be claimed by the surgeons, but his discovery of the anæsthetic properties of chloroform brought him very close to them. The story of his discovery is told elsewhere; here we need only acknowledge the debt that Surgery owes to his work.

One of the first to take advantage of it was James Syme, then at the height of his fame as Professor of Clinical Surgery. Syme did not belong to the school of brilliant surgeons, but as an operator he was one of the best. Even if his reputation depended merely on his operative work he would still rank as one of the greatest surgeons of all time; many of the procedures he devised are practised to-day in every detail as he first described them; some have been modified to suit altered conditions; but none has failed to stand the test of time.

But Syme was much more than a highly skilled craftsman, he was a trained scientific observer. As a boy, chemistry was his hobby, and he invented the substance known as "macintosh," in the course of his investigations on the distillation of coal tar. As a young graduate he took up the study of diseases of bones and joints, and made valuable additions to our knowledge of the disease known as caries of bone. This led on to his famous experiments on the bone-producing function of the periosteum, the results of which anticipated those of Ollier by twenty years. He also did much to improve the methods of treating incised wounds with a view of obtaining "healing by first intention," particularly by taking steps to prevent the accumulation of blood or inflammatory products, and his advocacy of "drainage of wounds" led to a marked improvement in this direction.

Syme was a pioneer, and one of the most successful advocates of the practice of excising diseased joints as an alternative to amputation—one of the most brilliant achievements of conservative Surgery. To attempt to assess Syme's share in the progress of Surgery in his own day, and the abiding influence of his work on the practice of ours, would lead us far beyond the limits here set us. His teaching and his practice were based on broad and sound general principles which he was ever trying to simplify. In 1863 his *Principles of Surgery* was simpler and clearer in its fifth edition than it had been thirty-two years earlier in its first. There were "few advances in Surgery that had not received some impulse from his indefatigable and vigorous mind"; in what proved to be his last clinical lecture he showed his acumen when he said of the work of Lister, then just beginning, that it "is certainly destined in no small degree to revolutionise the practice of Surgery." The extent to which it did revolutionise Surgery, and much besides, is now common knowledge, and the story of how it was all brought about need not be retold at length here.

Joseph Lister had literally seen the beginnings of the anæsthetic era of Surgery—he was present at Liston's first operation performed under ether in 1846; he had witnessed the surgical skill and dexterity of the most brilliant of the manipulative school of Surgeons; he had been attracted to Edinburgh by the fame of Syme as a scientific surgeon, and had remained as his House Surgeon, and, later, as Assistant Surgeon in the famous Royal Infirmary of Edinburgh. He had thus been in close contact with all that was best and most advanced in British Surgery, and was not wanting in appreciation of what he saw. But with it all something was lacking. Even in the hands of the masters the most carefully planned and skilfully performed operations too often ended in failure from the inflammatory complications that supervened. Many attempts had been made to improve matters by modifying the methods of operating, by employing special lotions for washing and dressing wounds, and by adopting new expedients in the after-treatment, but with little effect. Wounds continued to suppurate, and the spectre of sepsis ever dogged the footsteps of the surgeon. The frustration of the best efforts of the surgeon, and the sufferings of the patients, made a deep impression on Lister's sensitive nature, and prompted him to investigate the nature of the inflammatory process as it affects wounds, and the cause of the "unhealthy action" which gave rise to suppuration and all its sequelæ.

His classical study on the "Early Stages of Inflammation" laid the foundation of his later work. It settled many problems, but it raised as many new ones, each of which he took up and followed out with characteristic assiduity. Experiments on the effects of irritants on the distribution of the pigment in the stellate cells of the frog's web ; on the nervous mechanism for regulating the contraction of blood vessels ; on the process of coagulation of blood,—each threw some fresh light on his quest, without, however, revealing the essential cause of the phenomena he was investigating. That light came when Pasteur revealed the true nature of fermentation, and showed that it depends on the action of micro-organisms. Lister was quick to see the bearing of this discovery on his own work, and, by a series of observations too elaborate to quote here, he proved that the putrefaction of the discharges from wounds had a like cause. This point settled, there still remained the problem of how to prevent it, and the solving of this problem was Lister's great contribution to Surgery and to humanity.

To trace the influence of the antiseptic idea on the development of Surgery as an applied art would lead us far beyond the scope of the present note. Suffice it to say that Lister's work put the practice of operative Surgery on a sound scientific basis, and rendered possible all the advances that have been made since 1867. Nor need we stop to discuss the specious but fallacious distinction that some have sought to draw between "aseptic" and "antiseptic" Surgery. Lister's ideal was the exclusion of sepsis from wounds, and if the disciples of the so-called "aseptic" school succeed in doing so it is only by the use of "antiseptic" measures.

It was but natural that the most enthusiastic followers of Lister should be found among his colleagues and pupils in the Glasgow and Edinburgh Schools where his system had been evolved. To see his results was to believe; those who had not seen remained unbelievers. To convince them Lister accepted the invitation to the Chair of Clinical Surgery at University College, London, in 1877, and in the end he succeeded.

The further advances that have been made in Surgery in Edinburgh and elsewhere have for the most part been of a technical nature. The possibility of preventing infection of wounds opened up fields for the surgeon that had previously been closed to him. With the early exploration of one of these,—that concerned with abdominal surgery,—the Edinburgh School was specially associated through the work of Thomas Keith, whose skill in applying aseptic principles in the removal of ovarian tumours attracted world-wide attention. Abdominal, pelvic, thoracic and intra-cranial Surgery are all products, more or less directly, of the antiseptic idea, although coincident advances in physiology, biochemistry, bacteriology, pathology and other allied sciences have played a large part in bringing them to their present state.

The work of Thomas Annandale (Lister's successor), Patrick Heron Watson, Thomas Keith, Joseph Bell, John Duncan, John Chiene, F. M. Caird, and others, represents Edinburgh's share of the contribution which the successors of Lister have made to the common pool of surgical knowledge.

This cursory sketch of the history of Surgery in Edinburgh reveals only a part of the contribution made by the School to the progress of scientific Surgery. Edinburgh has always been a great teaching centre, and those of her sons who have gone forth from her gates imbued with her doctrines and traditions will be the last to deny her a share in the laurels they have garnered in the fields of science.

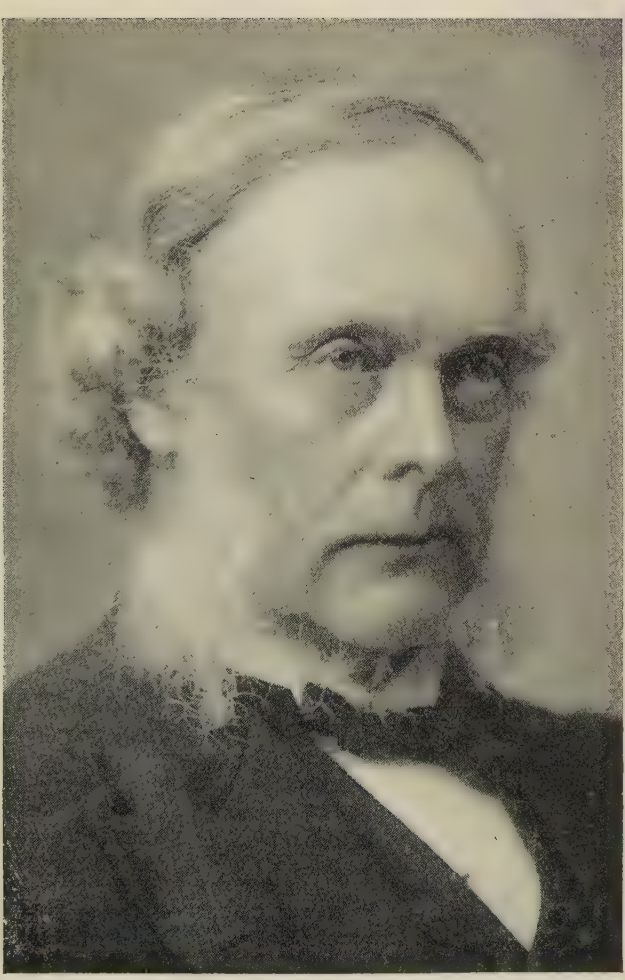
A. M.

MEDICAL SCHOOL SINCE 1870

The eight years from 1869 to 1877, during which Lister held the chair of Clinical Surgery in the University of Edinburgh, constitute one of the most important epochs in the development of medical science. While the antiseptic system of treating surgical wounds was suggested by Pasteur's work on putrefaction it really rested on an empirical and pragmatic basis. Essentially, the success of the treatment was its sanction, for it was not till the early eighties that the connection between definite bacterial species and the inflammations and suppurations of surgical wounds was actually proved, and the true meaning of the word putrefaction, as used by Lister, defined. The striking nature of Lister's results established the fundamental fact that somehow or other bacteria were responsible for surgical disasters, and favoured an attitude of receptivity towards the germ theory of infective disease in general which had been gradually emerging from the twilight research of the previous decade. During Lister's Professorship Edinburgh was the centre of interest for the whole medical world. The practical side of his work was eagerly followed by surgeons, but during the whole period he was engaged in scientific inquiries which not only were related to the development of the antiseptic system, but directed to investigating the nature and biology of the micro-organisms concerned in surgical infections. His experiments were characterised by great ingenuity and precision, and were a weighty contribution to the growing knowledge of the period. This knowledge culminated in Koch's work on anthrax, which furnished the first irrefragable proof of the germ theory of disease and formed the starting-point of the modern science of bacteriology. The termination of the long period of groping and uncertainty coincided with the end of Lister's Edinburgh Professorship.

In the late 'sixties of last century the continuous growth of the Edinburgh Medical School made it necessary for the University to face an enlargement of its accommodation for the teaching of Medicine. The progress of the project was slow, for its conception coincided with the movement to rebuild the Royal Infirmary. Not till 1877 were sufficient funds accumulated to justify an actual commencement of work being made, and eight more years elapsed before the medical departments were wholly transferred to the New Medical Buildings. While the University was thus provided with unequalled facilities for teaching it was somewhat unfortunate in the circumstance that its plans for extension were formulated before the necessity had been recognised of making adequate provision for the application of purely scientific methods to the problems of Medicine and Surgery. It has thus for thirty-five years laboured under the disadvantage of having a somewhat limited accommodation for research. Notwithstanding this, however, its staff and their pupils can show a worthy record of original work.

Of those who since Lister's time have made the Edinburgh School famous, two stand out pre-eminent,



LORD LISTER.

namely, the late Sir T. R. Fraser and Sir E. Sharpey Schafer. Fraser, while still a young man, had, along with Crum Brown, established for the first time the principle that a relationship exists between chemical constitution and pharmacological action, and his work with Christison on physostigmine had also brought him into notice. During his long tenure of the chair of Materia Medica his activities were characterised by an originality of mind which put him in the front rank of those who have built up the science of pharmacology in its present form. His investigations on strophanthus and on other cardiac stimulants placed the treatment of diseases of the heart on a new basis and paved the way for the more recent developments of this aspect of Medicine ; his researches regarding aconite are no less noteworthy. Though his results regarding the nature of snake venoms and on immunisation against these poisons were anticipated by Calmette, his observations were independent, and are all the more outstanding in that they were undertaken at a time when the phenomena of immunity were only beginning to be recognised. Sir E. Sharpey Schafer had in London established his great reputation for research as a physiologist and histologist. After taking up the Chair in his subject in the University of Edinburgh in 1899 he continued and developed his work on the subject of the internal secretions which is world-famous, and which has contributed a new chapter to knowledge regarding the bodily functions. Sir Edward's contributions to physiology since coming to Edinburgh have, however, not been confined to one aspect of the subject but have covered a wide field. They have included an elaboration of a new method of carrying out artificial respiration, several studies on the functions of the central nervous system, a reinvestigation of the phenomena following vagotomy and section of the spinal sympathetic (as a consequence of which new and unexpected facts emerged), observations on muscular contraction and on the changes occurring in muscle during contraction, contributions to the question of chloroform anæsthesia, an examination of the minute histological structure of the liver, and research upon the pulmonary circulation.

Apart from work which on account of its merit attracts the general attention of the scientific world, there has come from the Edinburgh School a constant stream of substantial contributions to knowledge which no one concerned in any subject to which they are related can afford to neglect. Thus in the Department of Anatomy, though, as elsewhere dealt with, Sir William Turner devoted himself chiefly to the comparative aspects of the subject, as his observations on the cetacea show, and to anthropology, his outstanding personality stimulated his pupils to investigations of the more human aspects of the subject. D. J. Cunningham laid the foundations of his reputation while he was Turner's Senior Assistant, and although his chief work was carried on while holding the Trinity College, Dublin, Chair, he continued it on succeeding to the Edinburgh Professorship. From 1878 on for twenty years the method of studying the relationship of the organs of the human body by means of large frozen sections was widely applied, especially by the gynecologists—by Hart to the normal pelvis, by Barbour to the mechanism of labour, by Ballantyne to the structure of the human fœtus, by Symington to that of the child, and by Webster to the puerperium and to ectopic gestation. During recent years in the Department of Anatomy under Professor Robinson the method of reconstructing fœtal structures by the superimposition of sheets of wax prepared to reproduce the features of microscopic sections has shed important light on embryological questions. In the surgical department, with all the encouragement which Professor Chiene's pupils always received from their Chief, Stiles carried out his work on the pathology of cancer of the breast, with special reference to the dissemination of malignant tumours. He was among the first to apply the paraffin method to morbid histology, and his research contributed to the scientific foundation for the modern surgical treatment of malignant disease. In the Department of Pathology, in the late 'seventies, D. J. Hamilton, afterwards Professor of Pathology in Aberdeen, did much to further morbid anatomy by his studies on inflammation and on the differences between caseating and ordinary bronchopneumonia, which he substantiated before the tuberculous causation of the former could be recognised. His successor, G. Sims Woodhead, commenced his pathological career with a study on the pathology of the nervous system. He was also the first to introduce into Edinburgh the then infant science of bacteriology, and along with Hare he published the first text-book on its technique which appeared in the English language. His own contributions were chiefly related to the pathology of tuberculosis, and his microscopic sections of whole lungs affected with this disease were of great value in elucidating the methods by which infection of the respiratory organs originates and progresses; they still form a material part of the teaching collection of the Department. He thereby acquired that familiarity with tuberculosis which afterwards led to his being appointed Chairman of the Tuberculosis Commission. Later (1889–98), a series of outstanding researches from the Department were those of Muir, who, in his study of the bone marrow, independently of Ehrlich, described the life-history of the leucocytes which originate in that tissue, and who made a notable contribution to knowledge of the pathology of blood diseases. From this Department also came Beattie's research on the infective origin of acute rheumatism, and at a later date a renewed study of the blood by Carnegie Dickson.

During the years of Sir E. Sharpey Schafer's professorship the Department of Physiology has been a constant source of important original work. Much of this has been related to the subject of internal secretion, and here the researches of Herring on the pituitary and of Swale Vincent are outstanding. Amongst other contributions to knowledge are those of Sutherland Simpson on the central nervous system and on bodily temperature, of Tait on the blood and blood coagulation, especially in the lower animal forms, of Cramer and Pringle and of Addis,—also on blood coagulation,—of Jolly on several aspects of nerve action, of Cramer on protagon, on the assimilation of proteins (with Pringle) and other problems of physiological chemistry, of Kojima on the endocrine glands.

As has already been pointed out in a previous article, an important feature of Edinburgh medicine is the existence side by side of two medical schools—that of the University, which prepares students for its own degrees, and the Extramural, which under the auspices of the Royal College of Physicians and of the Royal College of Surgeons offers courses qualifying for the Licence of these Corporations. The relationships of the two schools have always been a puzzle to outsiders, largely from the fact that the University can recognise a certain number of extramural courses as qualifying for its degrees. The body of extramural teachers is constituted on a basis of tradition of which catholicity and freedom are the main features. Any one who can satisfy a Committee of one or other Corporation that he possesses a knowledge of a subject, a gift of exposition, and a sufficient teaching apparatus, may obtain recognition as a Lecturer, and subsequent success in attracting students in competition with other Lecturers depends on his own ability and energy. While teaching has been the main purpose of the extramural Lecturer, there have always been those who found time to advance their subjects by research. The anatomical work of Symington, already alluded to, falls under such a category, and further examples are found in Alexander Bruce's observations on the minute structure of the central nervous system, and the discovery of the so-called fuchsin bodies in cancer by Russell, who was amongst the earliest to stimulate inquiry into the minuter cytology of malignant growths.

To provide facilities for the growing tendency towards original work outside the University the Royal College of Physicians, in 1889, took the important step of setting up a research laboratory, and its organisation was entrusted to Woodhead, who, by the qualities he had exhibited in the University Department of Pathology, was marked out as one specially fitted to direct the energies of those taking up original work. The College carried on the Laboratory at its own charges till 1903. In that year the Carnegie Trust for the Universities of Scotland, recognising the important place the Laboratory had filled, became partners in its control and supported it financially under the Research Scheme of the Trust. From the commencement the Royal College of Surgeons has given its aid to the Laboratory, and within late years the University has also become a contributor to its upkeep. During its existence a constant stream of papers bearing on the scientific aspects of Medicine and Surgery has issued from the Laboratory. These have been the work of extramural teachers or of young graduates who, before passing into practice, or in their earlier years in practice, have thereby acquired that scientific habit of mind which inevitably raises the standard of professional attainment. During the early years of the Laboratory it was the place where many of those who had been assistants in University Departments and who had become Extramural Lecturers continued their researches. Among these were Hart, Barbour, Ballantyne and Webster, to whom reference has already been made. Among others working on anatomical subjects were Bruce, who continued his observations on the minuter structure of the central nervous system, and Berry, who made a special study of the Regional Anatomy of the Abdomen. In Surgery, there were the experimental inquiries of Miles into the conditions under which injuries to the brain occur, and Thomson's observations on tuberculosis of bone. In pharmacology, much of R. Stockman's earlier work was carried on in the Laboratory, such as his researches on narcotine and quinoline and his studies of the distribution of iron in the bodily organs in the anæmias. In pathology there was Gulland's work on blood diseases and of the bearing of data derivable from such conditions on the origin and life-history of the blood corpuscles. When Noel Paton succeeded Woodhead as superintendent he developed research on physiological lines, and especially in the application of chemistry to the problems of internal metabolism. Important work was done on dietetics, an example of which is the investigation of prison diets by Dunlop, who also studied the effects of muscular work. Paton also organised extensive researches on the functions of the ductless glands, especially of the thymus. As a member of a Royal Commission he investigated the habits of the salmon and brought out the rather startling fact that in that fish an atrophy of the gastric mucous membrane occurs on its ascending a river, and that it does not feed in fresh water. As an adjunct of this inquiry Patterson adduced evidence for believing that the salmon only becomes attacked by the saprolegnia fungus when it is the victim of a bacillary infection. On Paton going to Glasgow as Professor of Physiology, work in the Laboratory, under the direction of the writer of this article, rather reverted to pathology and bacteriology. An important series of researches were carried on by J. Fraser, by Mitchell and by Wang, regarding the relative frequency of infection by the human and by the bovine strains of the tubercle bacillus, and there was demonstrated that in diseases of bones and joints and of glands the milk of tuberculous cows is responsible for a predominant proportion of the infections which occur. Amongst other notable work of this period are the researches of M'Gowan on the bacterial diseases of domestic animals, of which his investigation of the bacillary origin of canine distemper is specially important, those of Dawson on the morbid anatomy of disseminated sclerosis, and of Addis on hæmophilia.

In closing this brief record of the past achievements of the Edinburgh Medical School, reference must be made to the part its members played in the earlier development of microscopic technique. In 1870, A. B. Stirling, sub-curator of the Anatomical Museum under Goodsir and Turner, published an account of a new mechanism for the cutting of microscopic sections. Stirling was a self-taught working man of very original ability who developed extraordinary skill in all departments of museum work. His microtome was the result of his being baffled in dealing with a desire on the part of Goodsir to have sections of parts of the brain larger than could be cut by hand. It consisted essentially of an upright tube with open top and a movable bottom which could be raised by a micrometer screw. The object to be cut was fixed in the tube and successive thin slices could be shaved off its top by raising the block by operating the screw. The instrument was elaborated by Rutherford, afterwards Professor of Physiology, who embedded the object in gum in the tube and surrounded the latter with a freezing mixture. Hamilton, of the Pathology Department, introduced the further improvement of substituting gum and syrup for gum, the brittleness of which was a disadvantage. Another advance in the technique of cutting sections was initiated by Roy, afterwards Professor of Pathology in Cambridge, who introduced the principle of freezing the object with ether. Cathcart, in 1883, devised the microtome associated with his name, the feature of which was a much improved method of securing a satisfactory ether spray, and his instrument is still in use, especially in pathological work where the microscopic examination of tissues within a few minutes of their removal from the body may be an important desideratum. The paraffin method has, of course, superseded the earlier technique of section cutting, but the developments described above played a definite part in the progress of histology.

The Corporation of Edinburgh has always been in the forefront in its public health administration. Its sewage farm at Craigentinny, where a large portion of the city's sewage is used for the cultivation of meadows, had been the first attempt on a large scale at this form of water-borne refuse disposal. John Roberton's *Medical Police* (Edinburgh, 1808) was the most important treatise on public hygiene after that of Johann Peter Frank. In more recent times, under the vigorous and enlightened guidance of Sir Henry Littlejohn as Medical Officer of Health, many reforms and developments were introduced which were in effect experiments of great value in their bearing on social science. The city was the first great Local Authority to introduce the compulsory notification of infectious disease, which it did in 1879, by means of a Local Act. The thorough way in which Sir Henry tackled the problems of a pure water supply and the systematic removal of refuse, has placed the city in the enviable position of having the lowest death-rate from typhoid fever in the world, and was a demonstration of the means by which intestinal infections originate, and of the methods by which their spread can be controlled. His proof that the prevalence of tuberculosis in households was inversely proportional to the number of rooms a family occupies was again a demonstration of the part which dosage of an infective agent plays in its pathogenicity, and the work constituted an important contribution to sanitary science. Any reference to the development of this branch of knowledge in Edinburgh would be incomplete if no notice were taken of the anti-tuberculosis organisation which, during the past thirty years, has been built up and perfected by Sir Robert Philip, now Professor of Tuberculosis in the University. Starting as a private movement its success so appealed to the charitable public that a Trust was formed which for years carried on the many lines of activity involved, till legislation laid on local authorities responsibility for dealing with tuberculous disease. When this came into force the organisation was, in 1912, taken over by the Corporation as the scheme for the city. The essential features of Sir Robert Philip's system included the opening of tuberculosis dispensaries, to which patients came for diagnosis and treatment, the education of the patients in a proper mode of living, and the following up of cases to their homes in order to ascertain whether the conditions of the household favoured the proper treatment of the disease and whether the principles laid down as to food and fresh air were being followed out. This domiciliary visitation was taken advantage of for the systematic examination of contacts, so that infection might be detected in its earliest stages. Provision was also made for sanatorium treatment in the Victoria Hospital, situated in the outskirts of the city, where it was possible for patients to live a completely open-air life. When the individual was definitely established on an up-grade course, he was transferred to a Farm Colony in the country, where, as improvement continued, he could be put to light work and thus prepared for resuming ordinary life. The development of this great and complex mechanism, conceived on scientific lines, has been studied by all who are concerned in the fight against tuberculosis, and it has been taken as a model for similar organisations all over the world.

The war burst over the Edinburgh School in the act of inaugurating a new enterprise for extension and development. Only a few months before, the three great Corporations—the University, the Royal College of Physicians and the Royal College of Surgeons—had entered into an agreement for the promotion of a memorial of Lister, to take the form of an institute for medical research which would include new teaching departments for the University Departments of Pathology and Bacteriology. The scheme had reached the stage of negotiation for a site, 2¼ acres in extent, to the north-west of the Royal Infirmary. In the face of great difficulties these negotiations were concluded in the end of 1914, and it is only now that the parties concerned are resuming their interrupted efforts towards the attainment of their aim. During the war the activities of the School in the way of original work were almost entirely suspended. The various departments lost practically all the junior members of their staffs, and the energies of the professors were wholly occupied with the duties of teaching. Nevertheless, during the years of leanness developments have occurred. The work of the Chair of Bacteriology, founded by Robert Irvine of Royston, Granton, in 1913, is being developed. The Chair of Materia Medica is now chiefly devoted to the subject of Pharmacology. It became vacant in 1918 through the resignation of Sir Thomas Fraser, and Professor A. R. Cushny was elected as his successor. The Professor of Materia Medica had, up till then, been also one of the Professors of Clinical Medicine, with charge of wards in the Royal Infirmary. These are now attached to a new Chair,—the Christison Professorship of Therapeutics,—and in 1919 Professor J. Meakins was brought from M'Gill University, Montreal, as its first occupant. The conditions of the office are that he shall devote his whole time to the care of patients and to teaching and research in his subject. For the fulfilment of the last duty he has been provided with a research laboratory within the Infirmary at the joint expense of the University and the Infirmary Board. In 1919 the growth of the Department of Chemistry led to a new professorship being created for the instruction of students of Medicine in this subject. Professor Barger was inducted as the first occupant of the Chair, and the removal of pure chemistry from the Medical Buildings, which is in process of accomplishment, will facilitate his being provided with a research department adequate to his requirements. These developments must all work to continued progress in scientific Medicine in Edinburgh in the future.

J. R.

XII

DENTISTRY

DENTISTRY in some rude fashion has doubtless been practised from the advent of Man upon earth, but its practice, till quite recent times, rested on no basis of scientific knowledge. William Hunter, a great Scotsman, was responsible for the first authoritative works on *The Anatomy and Physiology of the Teeth,* published between 1771 and 1778. In the interval between his death and the appearance of Goodsir on the scene, but little advance took place. Goodsir, born in 1814, was apprenticed to Mr Nasmyth, F.R.C.S., an eminent dentist in Edinburgh, and it was while with Nasmyth that he investigated the development and structure of the teeth. This notable research stamped him as an original observer, swift to perceive, and displaying singular acuteness and accuracy in his deductions. His essay on the *Development of the Teeth* was published in the *Edinburgh Medical and Surgical Journal* for January 1837, and may be regarded as the most important contribution to dental histology that had, up to that time, appeared. Goodsir soon abandoned the practice of the dental art, finding that the arduous nature of the work made calls upon his energy to such an extent as to diminish both the time and the strength he desired to devote to the pursuit of science. Nevertheless, he was wont to attribute much of his manipulative skill to his training as a dental apprentice. This skill he turned to good account while Conservator of the Museum of the Royal College of

Surgeons, and later while occupying the Chair of Anatomy in the University, by the preparation of the beautifully executed dissections and specimens which still adorn the Anatomical Museum. He died in 1867, and was succeeded as Professor of Anatomy by William Turner. Among Sir William Turner's many contributions to anatomical knowledge may here be cited his report on the teeth of the Ziphoid Cetaceans (*Challenger Reports*), and his observation of the presence in the fœtal narwhal of the germs of a second pair of incisors, which are abortive and do not proceed to development.

The strength of Edinburgh as a centre of scientific progress in Medicine and the allied sciences has long lain in the excellence of her teaching schools, and by the middle of the nineteenth century her leading dental practitioners realised that the time was ripe for the provision of a proper education for dentists. Dr John Smith first gave a comprehensive course of lectures in Surgeons' Hall in 1856. In 1860, with the cordial co-operation of his professional colleagues, he established the Dental Dispensary, which ultimately became the present Edinburgh Dental Hospital and School. The passing of the Dentists' Act in 1878 led the Royal College of Surgeons to institute a Licence in Dental Surgery. This brought students from all parts of the world to take the dental curriculum in Edinburgh. There are at the time of writing upwards of 200 dental students in attendance, studying for a diploma which is everywhere and deservedly held in high repute. As an incentive to post-graduate study a Higher Dental Diploma has recently been established by the College. Candidates for this diploma are required to show a very high degree of knowledge and skill. In the Dental School much good work has been done, and although no epoch-making discovery stands to the credit of the staff, many useful contributions to knowledge have been made, and many improvements in practice and treatment suggested, notably in respect of the action of various anæsthetics and anæsthetic mixtures, and the perfecting of the technique of their administration.

The Odonto-Chirurgical Society of Scotland was founded in 1867, with Mr Nasmyth as its first President. It has ever since been an active and effective factor in the promotion of dental science, and still flourishes with undiminished vigour.

To-day, when the influence of oral sepsis as a prime or contributory cause of many local and general manifestations of disease is universally recognised, it is interesting to recall the fact that it was an Edinburgh graduate, Dr William Hunter, who, twenty-one years ago, impressed on the medical profession the importance of diagnosing and treating this condition, and of taking all possible measures to prevent its occurrence.

W. G.

XIII

POLITICAL ECONOMY

IN the development of Banking, Accounting, Insurance, Education, Law and Government, and the other forms of Immaterial Capital and Organisation that are now so much stressed, Edinburgh for a long period took the predominant part in Scotland. This lead in the higher forms of business was naturally associated with a corresponding lead in the development of economic science. The early Edinburgh economists, however, were by no means simply men of business. On the contrary, some of them—strange as it may seem to us—were romantic in character, and were associated with events of a romantic order. Later on their breadth of view was shown by their distinction in literature, philosophy, divinity, and history. The tradition of political economy in Scotland, and especially in Edinburgh, is humanistic in the best sense of the term. Adam Smith, the greatest of all economists, was probably the best all-round thinker of his day. But there were kings before Agamemnon, and economists before Adam Smith.

William Paterson (1658–1719) will always be remembered as the propounder of two great schemes—one a remarkable success and the other a lamentable failure. He was the founder of the Bank of England, and the projector of the ill-fated Darien scheme. The Darien scheme (the germ of the Panama Canal) was born into this world before its time. The ruling idea was to establish a colony in the isthmus of Darien.

The colony was to be called New Caledonia, and the chief town New Edinburgh. It was expected to be the great *entrepôt* between the East and the West. The romantic character of Paterson is shown by his description of his colony as "the door of the seas, and the key of the universe, that will enable its proprietors to give laws to both oceans and become the arbitrators of the commercial world." The scheme failed mainly through the hostility of England, and the failure aroused great resentment throughout Scotland. The writings of Paterson show that he was a master of the principles of banking and credit, and in particular that he knew the evils and dangers of inconvertible paper as clearly as if he had had the experience of our great war finance.

The fame of Paterson was eclipsed by that of John Law (1671–1729). He was born in Edinburgh. His father, a goldsmith (and primitive banker), made a fortune and bought Lauriston Castle and estate. John Law succeeded when only fourteen, and was henceforth always called John Law of Lauriston. His career from beginning to end was of the most romantic character. He was sentenced to death at twenty-one for killing another man of fashion in a duel (the woman in the case being a married lady). He fled to Holland, and there learned at first hand the principles of trade and banking. On his return to Scotland, after a full pardon, he published at the age of thirty a plan for a *Council of Trade*, and when this ambitious scheme failed to find support he tried to reform the currency and credit systems of his country. With this object he wrote his chief work on *Money and Trade*. Like Paterson, he anticipated the main principles of banking. When he found that his proposals were too advanced for Scotland he returned to the Continent and visited the chief cities of Europe, studying finance and practising speculation. Recent researches have revealed a scheme for the establishment of a bank in Turin, which was perfectly sound. In 1715, on the assumption of the Regency by the Duke of Orleans, John Law came to Paris with a fortune of

£100,000. From 1716–20 occurred the series of events that made John Law the most famous man in the world. He was in truth the Napoleon of finance, and if, like Napoleon, he met his Waterloo, none the less he was a genius of the first rank. John Law's Bank in Paris was at first a great success, and was ruined by conversion into a Royal Bank with the degenerate Regent as the patron. The story of "the system"—John Law's was *the* system *par excellence*—and of the Mississippi scheme are part of universal history, and may here be passed over. A vast literature has grown up around John Law. Any new thing about him is still a matter of interest. Quite recently a discussion has taken place on the reasons which made the French pronounce the word Law—*Las*. He took his failure with a great heart, and left the whole of his fortune in Paris. He was buried in Venice (1729).

David Hume (1711–76) was born in Edinburgh. After some years spent abroad he was appointed librarian of the Faculty of Advocates. In the same year he published a volume of *Economic Essays* under the title of *Political Discourses*. He anticipated, and put with great vigour, some of the main ideas of Adam Smith, *e.g.* on the balance of trade, the effects of the quantity of money on prices, the relations of labour to wealth. His position as a psychologist is discussed under Psychology.

Hume and Adam Smith were most intimate friends. Their letters begin "My dearest Friend," the last interchange being two days before Hume's death—August 1776. Hume was buried in the Calton, and "the great round tower" was designed by Robert Adam, and put up at Hume's own request. Adam Smith is reported to have said of it: "I don't like that monument; it is the greatest piece of vanity I ever saw in my friend Hume."

The next notable forerunner of Adam Smith in Edinburgh was Sir James Steuart (1712–80). He also was a romantic. He was the only son of the Solicitor-General

ADAM SMITH.

From Medallion by Tassie in Scottish National Portrait Gallery.

for Scotland, and was himself admitted as an advocate in 1735. He then made the grand tour according to the custom of the time, and at Rome was presented to the Young Pretender. He became a devoted adherent, and drew up the manifesto addressed to the people of England for the Jacobite rising of 1745. After Culloden he was in exile in Europe for about twenty years; but was readmitted to the full rights of an Edinburgh citizen in 1767. His great work was entitled an *Inquiry into the Principles of Political Economy* (1770), with special mention of the most important topics—Population, Agriculture, Trade, Industry, Money Banks, Public Credit, and Taxes.

Steuart describes his work as a canvas for better hands than his to work on, as if forecasting the greater *Inquiry* by Adam Smith.

Adam Smith (1723–90) began life with a touch of romance—being stolen by gipsies. This event was, perhaps, the germ of his love of natural liberty. Later on he became Professor of Moral Philosophy in Glasgow, and later still a Commissioner of Customs resident in Edinburgh. If we judge only by the amount of literature it has called forth in every country, the *Wealth of Nations* (1776) is one of the world's most notable books. Its enduring influence and popularity are accounted for by the originality and the broad-mindedness of the author. Adam Smith was a profound thinker in moral philosophy and jurisprudence, and a historian of the first rank. He had a wide knowledge of literature, and was especially devoted to Greek poetry. Amongst the by-products of his genius may be mentioned an essay on dancing and a history of astronomy. The connection of Adam Smith with Edinburgh was of the closest. He took part in the foundation of the first *Edinburgh Review*, and contributed to the first number a review of Johnson's *Dictionary*, and to the second (and last) an account of the state of contemporary literature in all the countries of Europe. In 1770 he received the Freedom of the City—" in the most ample form."

Adam Smith was one of the founders of the Royal Society of Edinburgh, which was at first divided into two parts—scientific and literary—and Smith became President of the literary branch. Adam Smith was of a cheerful disposition, and delighted in making others cheerful. An interesting account is given by a French Professor of Geology who was entertained by Smith in Edinburgh. On hearing that his guest liked music he took him to a bagpipe competition, which, with the dancing, made the most vivid and lasting impression on the Frenchman. Amongst other accomplishments (or duties) Adam Smith accepted the honorary Captaincy of the Trained Bands of the City (the City Guard).

From 1778 Adam Smith resided in Edinburgh at Panmure House, at the foot of Panmure Close, one of the steep and narrow wynds that descend from the north side of the Canongate towards the base of the Calton Hill. At the entrance to the close there is a circular tablet: "In Panmure House on the East side of this close Adam Smith lived 1778 to 1790." The house is now used as a stable and store. Adam Smith's grave in the Canongate Churchyard is marked by a simple tombstone, much less imposing than that in honour of his friend, Dugald Stewart. It is interesting to note that the year of the death of Adam Smith, James Mill (the father of John Stuart) entered Edinburgh University, and completed the course usual at the time.

David Macpherson (1746–1816) was the son of an Edinburgh clothier. He published (1805) his monumental *Annals of Commerce* (four vols. 4to)—for a long period the standard work on the subject. He incorporated the *Annals* of Adam Anderson (1692–1765).

John Ramsay M'Culloch (1789–1864) was a student of Edinburgh University, and was trained as a Writer to the Signet. He soon abandoned law, and devoted himself to economics. For ten years (1817–27) he contributed the economic articles to the *Scotsman*, and for two years, 1818–19, he was editor. M'Culloch was a most voluminous writer. On the scientific side he was greatly under the influence of Ricardo. But no writer on economics was more in touch with statistical and realistic economics as shown by his great *Dictionary—Practical, Theoretical, and Historical of Commerce and Commercial Navigation* (1641). Before he was displaced by Mill, M'Culloch was regarded as the leading authority on economics.

Sir Walter Scott, under the pseudonym of Malachi Malagrowther, wrote (1826) to the Edinburgh *Weekly Journal* three letters on Currency, which show a thorough grasp of the history of Scottish banking, and of its fundamental principles. It was mainly owing to these letters that the abolition of the One Pound note was prevented in Scotland.

Thomas de Quincey (1785–1860) also made incursions into the economic field during his residence in Edinburgh from 1832—his most ambitious effort being entitled *Logic of Political Economy* (1844), also described as *Prolegomena to all Future Systems of Political Economy.*

Thomas Chalmers (1780–1847)—Dr Chalmers of Free Church fame—was Professor of Divinity in Edinburgh University (1828–43), and his book on Political Economy was written "as by an ecclesiastic who values economics." Dr Chalmers also united the scientific with the practical. His experiment in the organisation of charitable relief in Glasgow, begun 1815, is one of the most notable examples of voluntary effort. His *Christian and Civic Economy of our Large Towns* was published in 1821. He was a mathematician and the originator of the term "margin of cultivation," and in that way of the application of the idea of marginal increments.

H. C. Fleeming Jenkin (1833–85), Professor of Engineering in Edinburgh, wrote highly original papers, dealing with the mathematical treatment of demand and supply, especially in relation to labour, wages, and trade unions. These papers will be found in *Papers Literary, Scientific, etc.* (1888), edited by Sydney Colvin and J. A. Ewing (now Principal of Edinburgh University), with *Memoir* by R. L. Stevenson.

Robert Flint (1838–1909) was Professor of Moral Philosophy and Political Economy at St. Andrews (1864–76) and of Divinity at Edinburgh (1876–1903). He was one of the most learned men of his time and an earnest and eloquent preacher. His best known economic work is *Socialism* (1894; revised 1908).

William Cunningham (1849–1919), Archdeacon of Ely, was an Edinburgh man, and is specially interesting as carrying on the Scottish tradition of the connection of Economics with philosophy and divinity, and also as the successor to Anderson and Macpherson as the standard writer on Economic History.

As already pointed out, Political Economy was treated in the University as part of Moral Philosophy. But in 1870 a separate Chair was founded and endowed by the Edinburgh Merchant Company. The first occupant of the Chair was W. B. Hodgson (1815–80), who left no works of economic importance, though in his day his lectures and pamphlets had considerable influence. He carried on the tradition of combining literature with economics—his book on *Errors in the Use of English* (1882) being a well-known work of reference.

The Chair founded in 1870 included in its nominal title Mercantile Law and other allied subjects. In the course of time this Chair has been supplemented by a Professorship of Accounting, and special Lectureships in Mercantile Law, Economic History, Statistics and Mathematical Economics, Banking, Organisation of Commerce, Economic Geography, and Realistic Economics. The subject of Political Economy is now compulsory for the degree of B.Com., and for the B.Sc. (Agric.), and is optional for M.A., LL.B.

J. S. N.

PSYCHOLOGY

PSYCHOLOGY is an old study but a young science. As a branch of metaphysics it has been assiduously pursued since early Greek times; as one of the recognised biological sciences it is but of yesterday. The change that has taken place is a very notable and, for psychology itself, a momentous one. In tracing the change to its source we are brought back to two of the greatest names in the records of British thought, an Englishman and a Scot respectively—John Locke (1632–1704) and David Hume (1711–76). There can be no question that the founder of modern psychology was John Locke, and this both in its general and in its experimental aspects. From John Locke derive alike Condillac and the Sensationalists, Hartley and the English Associationists, Hume, Reid, and the Scottish School, to say nothing of Kant and modern German philosophical thought. But, if all the lines of the development of modern psychology thus lead back to Locke, what is in a peculiar sense a key position is occupied by David Hume. It was really David Hume who, more than any other, gave its impetus to the movement in psychology and in philosophy, of which, as M'Dougall has said, "no man can yet see the final issue," but of which one issue at least has been the scientific psychology of the present day.

Here is Baldwin's estimate of Hume: "His psychology is one of those systems whose very radicalness and freedom from ambiguity make them typical and influential, not only positively, but as targets for the practice of riflemen generally." And again: "In method he was an experimentalist, a positivist, admitting no intrusions from metaphysics, no dogmatic assumptions. His results were in a measure personal to him . . . . but in his principles of association and habit, no less than in his sensational theory of knowledge, Hume worked out views which have been and still are of enormous influence." This is the estimate of one of the leading representatives of modern psychology, and it is without doubt sound. David Hume must be reckoned as one of the first and greatest of the prophets of modern psychology.

David Hume came of a Border family and was born in Edinburgh, where he lived the greater part of his life. From 1763 to 1769 he acted as secretary to the embassy in Paris, where he became familiar with the leaders of Parisian thought and society of the time, continuing to correspond with many of them, both men and women, after his return to Edinburgh. See Hill Burton's *Life and Correspondence of David Hume* (1846). The original letters are preserved in the Library of the Royal Society of Edinburgh with some of Hume's historical manuscripts. As an historian and economist (see page 240) Hume takes high rank, but it is as a philosopher and psychologist that he will be longest remembered.

We cannot resist the temptation to re-tell the well-known story—it is a pity it is of somewhat doubtful authenticity—of how St. David Street got its name from David Hume. The story is that a young lady friend, in a waggish mood, chalked up the name on the corner of Hume's house. The servant-maid, regarding the inscription as a rather unjustifiable joke at her master's expense, and an unwarrantable liberty, and so expressing herself to Hume, got the reply: "Never mind, lassie; many a better man has been made a saint before now." A tablet marks the house occupied by Hume in St. David Street (No. 21).

What a galaxy of psychological talent is represented in the Edinburgh of Hume's and the following generations. David Hume himself, Adam Smith, Lord Kames, Adam Ferguson, Dugald Stewart, Thomas Brown, John Abercrombie, Sir William Hamilton, George Combe—all these were Edinburgh men by birth or by adoption, and all are notable in the history of modern psychology. James Mill was a student at the University of Edinburgh, as were also both the Darwins, Erasmus and Charles, James Braid, W. B. Carpenter and Thomas Laycock. Many of these names stand high among the representatives of other thought developments; but their position is also secure in the records of British psychology.

Dugald Stewart (1753–1810) was born within the Old Buildings of the University, where his father resided as Professor of Mathematics. As the occupant for many years of the Chair of Moral Philosophy, he exerted a great influence in the spread of the characteristic psychology of the Scottish School, his brilliancy as a lecturer and writer attracting students from all over the country and from the Continent. The influence was carried on by Thomas Brown, who succeeded Stewart in the Chair, and Sir William Hamilton, the famous Professor of Logic and Metaphysics: the former, however, tended towards English Associationism, and the latter towards the views in psychology and philosophy of the German school of Kant.

The exact position of the Scottish School in the development of modern psychology is worthy of special notice. Perhaps the leading characteristic of the Scottish School was that all its representatives, carrying on the tradition of Locke, attempt to base a metaphysical and ethical philosophy on a psychological foundation, in contradistinction to the German school of thought—Leibniz, Kant, Hegel, and their followers and successors—the representatives of which deduced a psychology from their metaphysical principles. As a result of this fundamental characteristic the Scottish

School developed introspective psychology to the highest pitch, and this introspective psychology may be said to have become the orthodox psychology of the nineteenth century, not merely in Britain, but also abroad, and more especially in France. The relations with English Associationism were very close; Dugald Stewart and Thomas Brown are generally reckoned as prominent representatives of the latter, as well as of the Scottish School. The influence on French psychology is important because of the fact that, while all the world was running after the new German psychology and its experimental methods, French psychology to a large extent held on an independent course, which has justified itself in the newer and wider psychology of the present. The relation to English Associationism is no less important, for English Associationism, like the French psychology, developed its own experimental methods on its own lines, as with Francis Galton, and is also an independent source of our present psychology. A late representative of the Scottish School was Simon S. Laurie, more famous as an educationist.

But it is not only the orthodox psychology of the past that owes a debt to Edinburgh and Edinburgh men. The phrenologists have long received much less than their due, and the time has surely come when it is possible to give them the credit they deserve, without incurring the danger of being ranked with them as impostors and charlatans. Apart from the foolish side of their teaching, that is, cranioscopy, the phrenologists undoubtedly did great service to the modern science, in that they played a not insignificant part in the development of physiological psychology, if only by supplying the stimulus to much work on the localisation of brain functions.

Among the phrenologists, George Combe (1788–1858) held an honourable place. He adopted the legal profession, but retired in 1837 with a fair competency to devote himself, throughout the remainder of his life, to the two great causes with which he identified himself, the spread of a knowledge of the true science and philosophy of human nature — in his opinion, phrenology—and the education of the working classes. Judged alike by his motives, and by the actual work he accomplished, more especially with regard to education, George Combe has been quite undeservedly forgotten by the present generation of his fellow-townsmen.

An interesting incident in Combe's life was his candidature for the Chair of Logic and Metaphysics in 1836, when Sir William Hamilton was appointed. Combe and Hamilton had previously carried on a lengthy and sometimes acrimonious controversy regarding the merits of phrenology, and feeling ran high in Edinburgh. Combe never had any chance of election to the Chair; but the amount of support he obtained from prominent men all over the world, and especially from the medical profession, was notable.

George Combe's brother, Andrew, is also deserving of mention. In addition to writing in support of phrenology from the medical or physiological side, Andrew Combe published a little work on *Mental Derangement,* which is now perhaps out of date, but which was in its day a pioneer work in several directions. The present Lectureship in Psychology in Edinburgh University was endowed by the Trustees of George and Andrew Combe.

Thomas Laycock, Professor of Clinical Medicine in the University from 1855–76, is another pioneer of modern psychology, whose name ought not to be entirely forgotten. He gave a regular course of lectures in Medical Psychology in the University—probably one of the earliest courses of this kind given in any university—and was an ardent student of those phenomena of the "unconscious," which occupy so prominent a place in psychological discussion to-day. In his book, *Mind and Brain* (1860), Laycock claims to be the originator of the doctrine of "unconscious cerebration," usually attributed to Carpenter. With Laycock, as with Carpenter, the doctrine is little more than a speculative physiological interpretation of Sir William Hamilton's "mental latency." Nevertheless, it still stands, pretty much as he left it, as one of the possible interpretations of the nature of the "unconscious."

Thomas Laycock is also notable for his early recognition of the scientific status and importance of the phenomena of hypnotism. The genuineness of the phenomena was not generally acknowledged by the scientific world even in Laycock's time, but Laycock—and Carpenter was also in agreement with him here—was convinced by the work of Braid that the phenomena were genuine, and also that Braid's explanation of the phenomena was on the right lines. To Braid himself Edinburgh University can lay claim as an *alumnus*. Most of his active life, it is true, was spent in medical practice in Manchester, and he is usually identified with that city, but none the less he was a Fife man by birth and an Edinburgh man by education. James Braid was attracted to the study of "mesmerism" or "animal magnetism," as it was then called, in 1841. He seems at the very outset to have grasped the real nature of the phenomena, and he was the first to use the term "hypnotism" to designate them. Braid read a paper to the Manchester meeting of the British Association in 1842 on "A Practical Essay in the Curative Agency of Neuro-Hypnotism." This gave his views currency. He followed the paper up with various works: *Neurypnology, or the Rationale of Nervous Sleep considered in Relation to Animal Magnetism* (1843); *The Power of the Mind over the Body* (1846); *Observations on Trance* (1850), etc. Laycock was a warm supporter of Braid's views, though they met with much opposition in the country at large. It is interesting to note that their value and importance were early recognised in France, and they remain the basis of a very significant and characteristic phase in the development of modern French psychology.

Sir Thomas Clouston—a student under Laycock, and subsequently Lecturer on Mental Diseases in the University—worthily maintained the traditions of medical psychology in Edinburgh. His *Hygiene of Mind* is still a standard work.

There is still another field of modern psychology in which the credit of pioneer work belongs to an Edinburgh man. Sir Charles Bell, one of the most distinguished of Edinburgh's scientists, and one of the most brilliant of the *alumni* of Edinburgh University, did pioneer work of the greatest value in the study of emotional expression. Bell's *Anatomy of Expression* was published soon after his migration to London in 1804; but it had been written before he left Edinburgh. This work attracted immediate attention, and it is historically important as initiating that line of inquiry which had its issue in Darwin's *Expression of the Emotions*—another epoch-making psychological work. The *Anatomy of Expression* is also historically important because of the fact that Bell was led along certain lines of thought entered upon there to the claims he afterwards made to priority in the discovery of the difference of function between the anterior and posterior roots of the spinal nerves, a discovery of the first importance for physiology. The relation of Bell's discovery to the later discoveries of Magendie is discussed on pages 203–4 in the article on Medicine and Surgery.

J. D.

XV

EDUCATIONAL SCIENCE

IT is no part of the aim of the present sketch to consider the place which Edinburgh has occupied, and occupies, in the history of education in general, as a phase of social and national development. That would be a very large subject indeed, and far beyond what is practicable within the limits imposed by present circumstances. Scottish education, of course, stands for certain definite principles and ideas in education, and so far Scotland's educational system and practice—and in a special degree as represented in its capital—have a direct bearing on educational science. That, however, is not the aspect of educational science with which we intend chiefly to concern ourselves at present. We wish rather to concentrate attention on the contributions of Edinburgh men to the development and systematisation of Educational Science as a definite study, and as a definite branch of applied science.

It is, nevertheless, perhaps worthy of a note in passing that the Scottish educational system is historically and educationally important in several aspects. It is a product of the Reformation, and has existed as a national system practically from the period of the Reformation. Hence, as was to be expected, this national system owes many of its characteristic features to the influence of John Knox, the leading spirit of the Reformation in Scotland. Probably the most significant of the essential and characteristic features of Scottish education, which have been present from the beginning, is its continuity from the primary school to the university. In the eighteenth century there was a greater proportion of the population possessed of a university education in Scotland than in any other country in Europe. In all likelihood this still holds good, and it is explained by the fact that the educational ladder has been complete from the lowest rung to the highest since the Scottish national system of education came into being.

It would have been a strange irony of fate, had a city with an educational history like that of Edinburgh made no significant contribution to the science of education itself. That is, however, far from being the case. Educational Science, in any strict sense, is of comparatively recent growth. As far as the English-speaking world is concerned, a very important part in its development as a systematic study was played by an Edinburgh man—Simon Somerville Laurie. In the history of Educational Science Laurie must take high rank. But his is not the only Edinburgh name which must take high rank. George Combe, already mentioned for his contributions to modern psychology, is even more distinguished as an early exponent of that scientific and practical view of education which found its later and more influential advocates in Huxley and Herbert Spencer.

Combe's place in the history of educational thought is secure. To some extent his work has been overshadowed by that of his great successors in the same field; but no one who knows the history of the development of the scientific tendency in education during the nineteenth century can fail to assign to the phrenologists, and among the phrenologists to George Combe first and foremost, the full credit that is due to them and to him, as the real originators of the tendency.

An earlier phase of the scientific movement had shown itself in the sense realism of the seventeenth century, which reached its culminating point in the teaching of John Amos Comenius. It is interesting to remember that this movement was first made familiar to English readers by Simon Laurie. But there is a distinct gap historically between the earlier and the later phases. The main current of educational thought in the interval is represented by the teaching, first of Locke, and later of Rousseau and his followers Basedow and Pestalozzi. The later scientific movement was a new movement in the sense in which any thought movement can be called new.

The great development of the physical and biological sciences, the increasing complexity of modern life, and especially of industrial life, the growth on the one hand of a physiological conscience, on the other hand of a social conscience—to these processes we must look for the main influences which led to the rise of the scientific tendency in modern education. These influences were focused on education in the first instance by the phrenologists, and by George Combe in particular, and this was the real beginning of the nineteenth century movement.

Two distinct lines of argument were pursued by George Combe in his educational theory. On the one hand—and this is the more important line of argument—he maintained that education should be before everything "practical," that is to say, that it should prepare the child to live his real life in a real world. In this connection he drew a very important distinction between what he called "instrumental" knowledge, and real, positive, or "practical" knowledge. Instrumental knowledge was knowledge which merely furnished the means for the attainment of future knowledge, and which had therefore no intrinsic value. Under this head he included languages and pure mathematics, the very subjects which were dominant in the education of the day. In Combe's view the result of this kind of education was that the pupil never reached in the school that positive and real knowedge, which ought to demand the first consideration.

Working out the practical implications of his theory, George Combe claimed that the subjects which ought to be considered of first importance are those which treat of the bodily constitution of the human being—anatomy and physiology. Next in order of importance come the subjects which treat of the mental constitution of man—psychology and ethics. Then those which treat of the physical environment in which man must live, followed by those which treat of his social environment.

His second line of argument is less important, and rests on his phrenology. Education, he maintains, must seek to train and develop the mental faculties. He himself subordinates this line of argument to the first, claiming that the requisite mental training is to be obtained as a by-product, while the knowledge that is of real practical value is being acquired.

The application of his principles to religious education, and the advocating of a purely secular education in the public schools, brought Combe into sharp conflict with the leaders of religious opinion in Scotland. It is undoubtedly one consequence of this that the work of George Combe is almost unknown to the present generation.

Simon Somerville Laurie (1829–1909) was born at Edinburgh and educated at the High School and the University, graduating M.A. in 1849. For some years he acted as assistant to Professor Pillans. Afterwards he travelled on the Continent with various private pupils, and for many years acted as Visitor to Schools, and Secretary to the Education Committee of the Church of Scotland, and also as Visitor and Examiner for the Dick Bequest. When the Bell Chair of Education was instituted in the University in 1876, Laurie became its first occupant, and he taught Education as a scheme there till 1903. He was also a distinguished later representative of the Scottish School of Philosophy, being Gifford Lecturer at Edinburgh for the years 1905–6.

The Bell Chair of Education at Edinburgh, along with that at St. Andrews, was the first Chair in Education in the world of the English speech, though the establishment of Chairs in some of the American universities followed close. The Chair in Edinburgh to some extent grew out of the Bell Lecture in Education, founded in 1831 by Andrew Bell, the originator of the Madras System, the Chair being established by his Trustees.

Laurie's position in the educational thought of his time was in keeping with his position as the first occupant of the first Chair in Education in any English-speaking country. He was a protagonist of the philosophical, as against the scientific, conception of education, as represented by Combe and Spencer, and he was the last great representative of a modified Discipline Theory. In the educational thought of to-day, the only man who occupies an analogous position is John Dewey. As Professor Darroch has put it, "the volume of his work on Education is much greater than that of any other writer since or during his time; with the possible exception of Herbert Spencer, his writings on Education have had a wider circulation and a greater influence than those of any other English writer." Laurie developed a systematic and complete theory of education as a whole. No English educationist since his day has attempted so much.

Mention might also be made of Alexander Melville Bell (1819–1905), who was born in Edinburgh and, following in his father's footsteps, took up elocution as a profession. He lectured on elocution to students of the University and the New College for over twenty years (1843–65). He then went to London, where he published his book *Visible Speech*; and in 1870 migrated to Canada as Lecturer on Philology in Queen's College, Kingston. In 1881 he removed to Washington, and thenceforward devoted himself to the education of deaf-mutes by his "visible speech" method. He wrote extensively on elocution, phonetics, and education, and ranks high among American educationists. See also page 27 for an account of his son, Graham Bell, the inventor of the telephone. J. D.

DAVID HUME.

From an Engraving by Martin after the Portrait by Allan Ramsay

XVI

SOCIAL REFORM

IT is not a little difficult to define the limits of Social Science, because all pioneer work is necessarily of social value. But there are certain branches of pioneer effort which may be held to have a more definite social significance than others, though even these tend to overlap with Medicine on the one side, and with Education on the other.

Great though may be the importance of the medical aspect of the work of Sir Robert Philip, in all probability its social importance is yet greater. For tuberculosis brings in its wake a series of social evils ; and at the same time efforts to cope with the scourge are found to touch many another problem. Realising this, Sir Robert Philip started the Anti-tuberculosis Dispensary movement.

The Royal Victoria Dispensary was opened in Edinburgh in the year 1887, and afforded the first practical instance of a scheme the object of which was "the co-ordination of efforts, applicable to all the different phases of the tuberculosis problem." Not only is the patient here impressed with his own responsibility in carrying out the treatment recommended, but by the "march past" all the other members of the family are examined. The danger of infection is greatly lessened, and the discovery of many cases in early stages renders cure much more possible. An essential feature of the Dispensary is that the home conditions of the family are carefully supervised. The Dispensary must be considered as part of a larger plan of treatment ; it acts as the clearing-house in which different stages of disease are dealt with. Connected with it are the Sanatorium, the Hospital for advanced cases, and the Farm Colony. It is this completeness of the idea that is the mainspring of its success.

While in 1900 only one such Dispensary existed in the whole world—that of Edinburgh—by 1911 there were several hundreds in operation in Great Britain, France, Germany, Belgium, Holland, Denmark, Sweden, Austria, the United States, and Canada. Other countries have shown in this way their belief in the soundness of the principles established by Sir Robert Philip, and the key to these principles is, that the solution of the problem is in the home—which is the greatest source of infection. It is just because the Dispensary can deal with home conditions that its success has been so great. Sir Robert Philip himself insists that the disease is so intimately bound up with the evils of civilisation that it cannot be dealt with without taking the social problems into consideration. For such a reason it may well be contended that Sir Robert Philip is one of the greatest social reformers of the present time.

Yet another branch of medical social work may be claimed for Edinburgh. The Boer War revealed an extraordinarily low standard of physique among recruits. In consequence, in the year 1902 a Royal Commission was appointed in Scotland to inquire into the State of Physical Training of School Children. In the year following a Departmental Committee was set up in England to inquire into the causes of the Physical Deterioration of the Race. On the recommendation of the Scottish Commission six hundred school children in Edinburgh and six hundred in Aberdeen were medically examined. Sir Leslie Mackenzie, who was responsible for the examination of the Edinburgh children, stated clearly in the conclusion of his report that "the large number of serious and minor diseases directly or indirectly affecting physical and mental efficiency constitutes an overwhelming case for a medical inspection of school children," and this, among other conclusions, was accepted and confirmed by the Commission. Similar conclusions were arrived at by the English Committee and, in consequence, the Education (Provision of Meals) Act was passed in England in 1906, followed in the next year by the Education (Administrative Provisions) Act, which introduced Medical Inspection. Not until 1908 were similar provisions made for Scotland. In consequence, by taking the Statutes alone into consideration, it would appear that Scotland followed England, whereas when the actual history of the movement is known it is seen that Scotland was first in recommending the system. This was largely through the work of Sir Leslie Mackenzie.

The history of social reform is now almost a science, for it is not at all impossible to predict in what direction the next development will take place. Medical inspection led to a realisation that special treatment was required for children suffering from various ailments. Again we find Edinburgh making an interesting experiment by starting a special school for children suffering from skin diseases. Instead of such children being left uneducated till the disease is cured, they are now gathered together at the Skin School in Lauriston Place, where they continue their education and receive treatment on the same premises. The school being situated almost next door to the Royal Infirmary, little time is wasted by children attending there for X-ray and other specialised treatment, and in consequence many a child, who might have grown up almost uneducated, because he had happened to have contracted a contagious disease, is now saved from this danger. This experiment has, needless to say, been copied elsewhere.

Equally, the medical examination of children of school age led to an appreciation of the need that existed for making provision for children before they attended school. In this direction it is difficult to say whether

Edinburgh has contributed anything of a definitely pioneer nature, as other cities were dealing with the same problem at the same time. It may, however, be the case that the Toddlers' Playgrounds were started in Edinburgh chiefly as the result of the suggestion of Dr A. K. Chalmers, that an experiment should be made with an open-air crèche. More recently the voluntary organisation of Health Visitors has started two fresh schemes, which are certain to spread. Acting upon a suggestion of Mrs Frances Johnston, M.D., a Rickets Clinic was opened for the treatment of early rickets by systematic and regular massage. The new feature here is that the clinic is for children below the age of five. Later, a Night Nursery was started where babies suffering from early rickets, or who are in contact with active tuberculosis, come in to sleep. These children live in one- or two-roomed houses where the overcrowding is such that dietetic supervision without some further treatment is quite insufficient. The babies are brought to the Night Nursery between 5 and 6 o'clock, bathed, given their supper, and put to bed in a room with windows permanently open. After breakfast they return home for the day with their mothers. Though it is yet too early definitely to state the results of these experiments, the probability is that the Rickets Clinic and the Night Nursery will soon be considered essential in any child welfare scheme.

Edinburgh has also contributed much in regard to the education of the blind. The first efforts in this direction were made in Liverpool in 1782, and Edinburgh started in the following year, when Dr Johnston, of North Leith Parish Church, founded the Blind Asylum Workshops in Nicolson Street. Thirty years later, James Gall started the Blind School, and to him lies the honour of having been the first man in the United Kingdom to print books for the blind, the type being named after him. The Edinburgh Society of Arts should also be famous for having offered a gold medal for the best system of tactile reading submitted to them. Systems were submitted from all parts of the world, and the Society by their action can claim to have greatly quickened the interest in the education of the blind. The next development in Edinburgh was in the founding of the Hostel for Women, and eventually the workshops, the school, and the hostel were amalgamated, the present institution being erected in 1878 to accommodate women and children. The education of the blind, started early in this City, has steadily developed. The standard reached is remarkably high, many of the pupils being able to pass on to the University. The Blind Asylum is one of the two places in the United Kingdom where books for the blind are printed.

Edinburgh, however, has not merely made contributions for those suffering from some definite physical disability. The Scots have a world-wide reputation in regard to their appreciation of the importance of education, and therefore it is not surprising that Edinburgh has led the way in establishing means by which education should not be wasted in after life. In November 1907, the Edinburgh School Board had an interview with Mrs Ogilvie Gordon, D.Sc., on the question of the Board establishing an Educational Bureau, where boys and girls leaving school could obtain guidance in the choice of employment. This led to the calling of a conference representative of public bodies, employers of labour, Trade Associations, and Headmasters of Day and Continuation Schools. As a result the Board agreed to establish an Educational Information and Employment Bureau, on the lines laid down by Mrs Ogilvie Gordon, in her book *Handbook of Employments*. The actual opening of the Bureau was deferred until the Education (Scotland) Act of 1908 came into force; but a start was made in September 1909. Meanwhile the idea was being considered elsewhere, and when the Board of Trade, at the beginning of the year 1910, established an Employment Exchange in Edinburgh, they found arrangements already made for dealing with juveniles. All that was necessary was a demarcation of function between the Exchange of the Board of Trade and that of the School Board.

In regard to continued education, Edinburgh has also done much pioneer work. Evening Schools in Scotland date back to about the year 1821, when the Watt School of Arts was founded, which later was incorporated in the Heriot-Watt College. By 1906 it was recognised that the co-operation of employers, and equally of parents, would be necessary if the idea of continued education was to gain ground. In consequence a committee was formed, of which Mr Gulland was the convener, and it was agreed to interview employers in order to enlist their sympathy. In this way industry was brought into school, advisory committees of employers being started, who helped in drawing up the curriculum. The advisory committees are now twenty-three in number, covering all the more important trades, each committee consisting of representatives of employers and operatives, with generally one educational expert. Practical work not unnaturally became an essential part of the scheme, and at the present time there is no other town in the United Kingdom where such complete workshop training is provided. Now that continued education is so much before the public, it is interesting to realise the part that Edinburgh has played in the movement.

No article on pioneer social work would be complete if it did not include some reference to Professor Patrick Geddes. It may seem unfitting to place him last, but his ideas are so comprehensive that it is well-nigh impossible to place them in any special group.

Trained originally as a biologist, Patrick Geddes began to give attention to the broad aspects of social life in the early eighties, when he published, in the *Proceedings of the Royal Society of Edinburgh*, two papers, one on the *Classification of Statistics*, and the other *An Analysis of the Principles of Economics*. Since then he has endeavoured, both by his writings and by the embodiment of his ideas in practical schemes, to incorporate in a complete sociology all that is essential in the recognised fundamental sciences, and in the still disconnected sub-sciences of sociology, economics, morals, history, anthropology, and the like. In Edinburgh, in the vicinity of the Castle, he established in the Outlook Tower what might be regarded as a training centre in the search for a true and complete sociology. The Outlook Tower is an old building formerly known as Short's Observatory, in which one of the most popular features was a Camera Obscura placed in the top of the turret, so as to throw down on a white table the reflected images of certain parts of Edinburgh, such as the Castle and Princes Street, with the traffic shown in full swing. This feature has been retained in the Outlook Tower; which otherwise, however, has been transformed into a miniature representation of what every University should possess in the form of an Institute, Museum, and Laboratory of Sociology and Civics. In the successive storeys methods of study are outlined as regards (1) the City itself; (2) Scotland; (3) the English-speaking world; (4) Europe; (5) the Orient and Man. Concrete results of Patrick Geddes's sociological schemes are to be seen in his University Halls for housing students, and his experiments in Town Planning and other developmental schemes in other regions and cities in the United Kingdom, the Continent, India, and Palestine.

Visitors to Edinburgh should not fail to visit the Outlook Tower, and endeavour to appreciate the ideals it represents. In fact, it is not unfitting to complete this short article on Edinburgh's contributions to Social Science by leaving the reader at the Tower, from which the city in all its beauty can be surveyed, and from which some idea may be gained of the form on which the city is planned, producing as it does a great social problem of "Edinburgh beneath the Bridges."

N. M.

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